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RESEARCH AND INDUSTRY

COOPERATION BETWEEN INDUSTRY AND UNIVERSITY[1]

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ANY one who has even superficially recognized the economic conditions of the world in which we live or who has attempted to analyze these conditions is impressed with the large rôle played by industrialism.

On the one hand is to be found that group termed "industrialists," whose work in the final analysis consists largely in the creation of financial profit from their investments. The other extreme, so to speak, is represented by scholars, housed in our universities, whose avowed purpose is the creation of a better world and the meeting and solving of the intellectual and practical problems confronting the modern age. Rarely has an adequate understanding between the two groups been reached. The average industrialist (I say average, because there are notable exceptions) feels the scholar to be quite out of touch with the "practical" problems of the day. He may vaguely admit a possible need for the thinker or the theorist, but to him the man of "action" is important. The scholar (and this includes the research scientist) is often moved with a feeling bordering upon contempt for the industrialist. He feels that aims, born and executed from a purely monetary standpoint, are, when viewed in the light of intellectual progress, futile and unworthy of serious consideration. As a result, we hear complaining voices grown eloquent in decrying the commercialization of our universities and the alleged lack of appreciation of knowledge for its own sake.

It is not my purpose here to weigh the special arguments of either group, since in my opinion the extremists on either side present conclusions based upon superficial grounds and so contribute little towards progress. I am interested in showing that, whether we like it or not, the problem of the relation between industry and university is with us and cries for answer. There is at least one answer to this question, which I will attempt to describe.

The life of every university depends upon its receiving, each year, the funds necessary for its conduct. These funds, whether received by the university as tuitions, endowments or taxes, represent a portion of the wealth produced over and above the actual living costs of the population of the community supporting the institution. In a previous age these moneys came largely from the fruit of the soil; to-day they result mainly from

[1] Paper presented before Section K—American Association for the Advancement of Science—Kansas City, Missouri, December 29, 1925.

the dividends paid directly or indirectly by industry. When industry ceases to pay dividends the university must close.

The life, the growth of industry depends directly upon the quality of the university scientist. Few industrialists understand this; captains of industry and finance, proud in the realization of their power and remembering the power plants, the fleets of ships or the compound locomotives which move at their command, vainly imagine that all this is their creation; the fruit of their dynamic, restless toil. Their only accomplishment is the organization and marshalling of certain forces. The forces which make possible all these activities were discovered, in almost every instance, by a scholar whose knowledge of either high finance or "scientific management" hardly equalled that of an office boy. Having made the observation he passed it on and turned to other problems. Instances of this, in almost every industrial field, could be endlessly related. Not long ago I heard an industrial group describe, in terms of admiration, the very large sum paid a comparatively young man for a radio business which he had "built up." I asked in what proportion the credit should be divided between this man and Clerk-Maxwell. They knew of no one in the radio business named Clerk-Maxwell. An industrial captain recently expressed his profound disapproval of the graduate school of a well-known university, maintaining that its cloistered walls unfitted students for grasping the important, practical problems of business. He was evidently ignorant of the fact that his own industry was born in such rooms; nor did he realize that the next and logical development of this industry is now awaiting the results of the work —not of his efficiency experts or business prognosticators—but of research scientists, whose very names he probably does not know.

I do not fear the commercialization of our universities. The strength and value of such institutions depends solely upon the character and ability of the men composing them. Strong men will not be commercialized. Nor need we be apprehensive lest the pursuit of knowledge for its own sake shall perish, or the love of scholarly pursuits, if we will only remind ourselves that human nature changes slowly, if at all. Scholars will continue in the future, as in the past, to represent a quite small percentage of the student rank and file, but they will continue in the future to appear and to do their work because they love it.

If scholars and industrialists will realize that their diverging tastes are equally legitimate (since even scholars must be fed, clothed and transported), that each is entitled to pursue the work at hand, and that, after all, they have something in common, both will be benefited. This common point of contact has, during the past four years, been partially achieved by the Tanners' Council of America and the University of Cincinnati.

The Tanners' Council is composed of the leather manufacturers of the United States. Tanning is a basic industry, since leather is needed for shoes, harness, belting, upholstery and many other uses. It is one of the largest American industries from the standpoint of capital investment. The tanning of leather was one of the first steps of civilized man. Throughout many ages and into the present day tanning was an empirical practice, the "secrets" of which were handed down from father to son. This was the result of an abundant supply of cheap raw material and mild competition. Under the stimulus of diminishing supplies of domestic raw materials and ever-increasing competition, a new viewpoint was born. Progressive members of the industry realized that if they were to maintain or advance their position,

the scientific laws underlying the materials and processes of their industry must be written.

The processes of tanning involve the conversion of the animal tissue skin into the useful, imputrescible article called leather, by means of tanning agents, both organic and inorganic. The science of tanning involves nearly every important branch of chemistry, just as in the problems of the modern medical investigator of other animal tissues; it involves also the action of bacteria and the histological picturing of structural changes. Such far-flung and fundamental studies called for a variety of scientific talent, for physical equipment and for time.

The council wisely turned to a university. A gentlemen's agreement with the University of Cincinnati was reached which has subsequently become the basis of a formal contract. The agreement is brief and simple and provides that: (1) no research work shall be undertaken which is not of a strictly fundamental character, which means, of course, that no "hack" work or special problems of particular contributing corporations will be considered; (2) the council will furnish the funds needed for the prosecution of the work; and (3) the results of all research will be freely published in reputable scientific journals.

From the viewpoint of the average industrialist the contract is unbusinesslike; from the standpoints of the really progressive manufacturer and the university it is the only adequate method of meeting the problem, of ensuring work of a fundamental quality and of attracting to it men of university caliber.

The agreement has "worked" in practice. During the early stages of the research there were, as would be expected, expressions of discontent from the less progressive, unimaginative members whose understanding of fundamental conceptions was necessarily vague and who expected the tree to grow to maturity and yield a golden crop within a month after planting. Another well-meaning group felt the urge of offering suggestions of "problems" demanding immediate attention, without, of course, any conception of whether their suggestions had a scientific basis. When such misdirected, though well-intentioned, efforts possess sufficient pressure, the scientist (whom the industrial group looks to for "results") often loses heart, his enthusiasm is dampened and, realizing the futility of the situation, he simply resigns. Or, if he lacks sturdiness, he is overawed by the powers before him and begins a necessarily fatal compromise; he seeks to pacify one group by investigating some probably wholly unessential problem they suggest. Scarcely is this done when another group, or a particular corporation, not to be outdone, advances with a suggestion; the precedent has been established and he must meet their demand. In a comparatively short period the scientist's time and energy are divided between routine analytical or testing work and a feverish effort to placate the ever-growing disappointment of the industrial group which had been led to expect large increases in their dividends. Thus the undertaking which started with the martial strains of a brass band ends with the weak notes of a harmonica. The net result is that a substantial sum of money has been wasted and nothing gained but disillusionment.

The foregoing conditions were realized by a committee of progressive members of the council, who took the steps necessary to safeguard the research laboratory. This committee functions as a buffer between the laboratory and the industry. Expressions of complaint or suggestions of problems are sent to them and are given consideration and reply. If the matter is of importance it is sub-

mitted to the laboratory, for the director's consideration. Thus, for four years, the laboratory at the University of Cincinnati has been enabled to concentrate upon essentials. It has formulated certain laws. For example: the curing of animal skin following slaughter is of great importance; the skin is cured so that it may be transported from abattoir to tannery without bacterial decomposition. The laws underlying this process were established, and to-day, instead of a heterogeneous mass of unrelated observations and data, there exist simple, clear-cut laws which govern the curing of any skin, be it rabbit, ox or elephant, and whether it is slaughtered in Chicago, Hong-Kong or Capetown. Again, a very important tannery process is termed "soaking," by which the skin is prepared for the unhairing treatment. The laws governing this process have been evolved. They have been applied by a dozen large corporations to meet their special conditions. Each of these corporations has been enabled to secure more and better leather from a unit of raw material and at no additional manufacturing cost. In other words, the work has produced wealth far in excess of its cost.

With the rapid but healthy expansion of the research work came the need of increased laboratory facilities. It was now no longer a question of whether the work would pay; this had been proved. The council consequently built and equipped upon the university campus a laboratory building which they gave to the university. This building is a handsome three-story brick and concrete structure, containing private research laboratories for the heads of the various departments of the work, general laboratories and private laboratories for post-graduate students, lecture-room and museum. One entire floor is devoted to chemical studies, another to bacteriology and a third to histology.

I have thus outlined one answer to the problem of the relation of university and industry. Wealth has been produced for industry and the university has been supplied the funds and facilities for the prosecution of scientific research. Each group has gained, neither has lost.

It may be correctly argued that the motive guiding the expenditures of the council lies mainly in the hope of greater profits rather than in the furtherance of knowledge for its own sake. Equally true, however, is the fact that these increased profits are the surest means of interesting industry in the general activities and aims of a university. If industry shall ultimately assume its proper share in supporting general education and research—whether in the arts, the sciences or the humanities—it will be because the university has shown itself to be the ultimate source of increased dividends.

THE FRONTIERS OF INDUSTRY[1]

By EARL P. STEVENSON

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We are indebted to many scholars of antiquity for bits of wisdom which, in their modern acceptance, can claim the quality of truth. There is the story of the emperor who called a conclave of scholars for the purpose of reducing the wisdom of the ages to a four-word summary, and on this present occasion the four-word report of that ancient convention is worthy of attention: "This too will change."

So long as industry deals with matter in the aggregate, considers the atom as an abstraction and the electron remains on the border-line of metaphysics, the opportunity for effecting fundamental changes in industrial processes should not be qualified. The field for useful inventions in the arts is kept fertile by new scientific discoveries, and never more so than to-day, with the quickening rewards of continued attack on the very substance of matter. The atom, as Dr. W. A. Whitney recently stated, presents a challenge for further study. "Thus far the more we have sought to understand them, the more we have gained in appreciation of an unexplored, unlimited territory of interest and service."

What new opportunities for achievement lie beyond the present frontiers of our scientific knowledge should not, however, be our only concern. The frontiers of science are further flung than those of industry; we must accept this fact and quicken our pace lest we pay further and greater tribute to those nations whose people have come to realize the great industrial opportunity that awaits a fuller appreciation of data already before us. We have passed through a period of epoch-making discoveries; if we are to more completely realize upon their potentialities our recourse is intensive research, wisely directed, adequately financed and sustained in the face of obstacles. To better cope with this situation, more energy should be concentrated on the frontiers of our industries.

Organized research does not depend upon individual genius; it is a group activity, as distinct a business activity as selling merchandise; it is as capable of organization and direction; so-called business methods are equally productive in its administration. Supermen are not required. While the individual may indulge the vagaries of his imagination, the realization is unavoidable that the immediate opportunity to-day is of a different kind than when Charles Watt in 1851 covered within the brief disclosure of a single patent specification the principles and practice of our present-day electrochemical industry. There are few such manuscripts as Watts' patent, British No. 13,755, for explicitness and inclusiveness. Consider the four brief claims:

Firstly, the mode of decomposition by the agency of electricity saline or other substances in solution by means of a vessel divided into two or more compartments separated from each other by partitions of porous material.

Secondly, the mode of preparing or obtaining the metals of the alkalies and alkaline earths by the action of electricity and heat.

Thirdly, the mode or modes of converting chlorides of potassium and sodium and the metallic base of the alkaline earths into hypochlorides, and chlorates of the alkalies and alkaline earths.

[1] Paper presented before Section K—American Association for the Advancement of Science—Kansas City, Missouri, December 29, 1925.

And fourthly, the separation of metals from each other by the agency of electricity and by means of vessels divided into compartments separated from each other by porous partitions and at the same time freeing such metals from other impurities.

Few are endowed with such genius as his for revealing new planets in our industrial system, but as the demand today is for intensive development, the tasks are of all orders, and many can qualify.

Possibly we are too much concerned with the evolution of industries, in effecting minor improvements in old processes, and under-emphasize in our research programs the opportunities for revolutionizing our practice of these processes. Living in the midst of abundant natural resources, we are not as responsive and sensitive to the significance of certain scientific observations in affording the suggestion of a new process as certain less endowed nations. We have so far been content, for example, in the exploitation of our petroleum reserves, with their utilization as fuel and lubricants; while the possibility of producing therefrom edible fats and oils, or developing a wide range of by-products, which affords a promise on a par with the coal-tar industry of twenty-five years ago, has not actively interested us. But this situation will change, is changing, in fact. We are coming to appreciate more the need for intensive research.

At this stage of our industrial development, a major advance in any field comprehends many collateral lines of work, often in superficially unrelated fields. Consider the instance of the new lacquer finishes which, within the past two years, have awakened the varnish industry from the feeling of security born of years of prosperity in the practice of processes inherited from the third century. To provide the automobile manufacturer with this new finish, the chemist can now obtain the necessary nitric acid through the fixation of atmospheric nitrogen; the cotton gin supplies the cellulose from the previously wasted linters; from coal and minerals come the colors; and, lastly, the essential ester solvents can be derived from petroleum. To this end the chemist has successfully exercised his art upon the entire known cross-section of the earth. This is but one example of the productiveness of systematic research.

Research, which gave to Germany her prewar monopoly of dyestuffs and to which she looks for her economic rehabilitation, is too often viewed apart as an ultra, rather than an intra, activity. The needs of research for financial support deserve recognition more on a par with the other agencies and divisions which comprise the machinery of production and distribution. In the face of millions for advertising products by slogans in the absence of distinctiveness in quality or utility which research alone could provide, research expenses are too frequently listed by the accountant among miscellaneous and sundries.

We have already paid the price of our failure to recognize in full the earning power of research. But a very few years ago, the American rights under the viscose patent for artificial silk went begging in this country for fifty thousand dollars, and last year witnessed the production in this country of thirty-six million pounds, valued at eighty-one million dollars, by a foreign-owned corporation that had the vision and faith necessary to finance this project through its development stages.

However parsimonious we may be in supporting fundamental industrial research, millions flow freely into the design of new and improved machinery for the operation of old processes. A million dollar expenditure on a new machine for forming sheet glass is considered quite in order, but glass is still brittle and easily shattered. A decrease in the insurance rates on plate glass is considered highly improbable, because the name glass connotes liability, and we continue

to pave our driveways with broken milk bottles because our milkman has not been sold to the idea that research could give him a tougher and less easily broken bottle.

While I could not justify the expense of a research directed toward a reversion in our preconceived ideas of glass, as there are more likely subjects in closer range of our present knowledge, a silk purse has, nevertheless, been made from a sow's ear. We may not always be dependent upon the fusible silicates for a transparent material. In fact, even now we hear from abroad of an organic glass, possessing remarkable properties, among which is the ready transmission of ultraviolet light. Its discovery was not an accident, but the culmination of years of work lacking in such tangible evidence of progress as might justify its continued support.

Examples without end could be cited where money has been liberally spent on machine design. A hundred thousand dollars to make a paper lard bucket in an automatic machine for your butcher's edification shows laudable enterprise. The idea can be sold and kept sold. The savings over one machine operation in contrast with three formerly used is tangible, and as the design progresses there is tangible evidence of progress. First comes a series of blue prints and pencil sketches—week by week gears are added and subtracted and new mechanical movements introduced—then comes in all probability a small wooden model that can be cranked by hand—later we have the assembly of a full-size model that doesn't perform, but never mind, the gears clank and it looks interesting. In the meantime, our more imaginative competitor has conceived an entirely new type of lard and ice-cream pail—a paper can, so our one hundred thousand dollar machine is idle most of the time.

A way should be found to place research, which aims to better utilize energy and materials for our daily use and is more concerned with primary processes, on a more even competitive basis for financial support with those projects which promise a more immediate return by effecting labor savings and larger scale operations in standard processes. This cause is undoubtedly advanced by such publicity as has been given the much-heralded new German process for making methanol from blue water gas. As the wood distillation industry in this country faces the possibility of losing its investment, which has been estimated at one hundred million dollars, it at last sees the handwriting on the wall. A few years ago, it is reported, an expenditure of eight thousand dollars a year for research was vetoed by the directors of one of these concerns in this country. The action, from one angle, was a proper one. The sum was entirely inadequate; but a request for fifty thousand dollars a year would never have had a hearing. The scheme would have been branded visionary at the directors' meeting, and the perusal of the current balance sheet would have continued, with much discussion of accounts receivable, for the auditor is a member in full and regular standing at these directors' meetings.

For reasons which I shall not attempt to further expound, the idea which is here entertained has found a more fertile field abroad. Our processes are too generally imported. The list is a long one, including the byproduct coking of coal, which in 1924 recovered values to the amount of one hundred and four million dollars formerly wasted by our beehive ovens; the flotation of ores not amenable to economic treatment by our purely mechanical processes; the fixation of atmospheric nitrogen; the viscose process for artificial silk; the basic syntheses for dye manufacture; both the Bessemer and the open hearth processes of the iron and steel industry; the sulfate process for pulping wood; and too many more.

Few of these fundamental processes of industries were without a substantial

prior art in advance of their commercialization. For example, the reaction between hydrogen and carbon monoxide which is employed in the new process for the synthesis of methyl alcohol was first noted by Solvay and Slense in 1898. Here was a recorded fact, but its commercial significance was not immediately apparent, and required years of research for its development. The Badische Company report 1914 as the starting date of its development of this process, which did not culminate in the installation of a commercial unit until 1924.

While numerous examples paralleling the instance of synthetic methyl alcohol could be cited, they would only serve to emphasize the apparent fact of the indebtedness of present-day industrial research to the past. Our concern should be rather to scan these volumes of scientific observations for suggestions of significance to the solution of current problems. The records of organic chemistry are rich in these suggestions, but I will limit myself to the mention of only two.

The gas companies of this country, with their aggregated investment in excess of a billion and a half, consume annually in the neighborhood of fifty million gallons of gas oil for the enrichment of blue water gas. This is a major cost amounting on an average to fifteen cents per millimeter with gas oil at five cents a gallon; moreover, the industry is concerned over its supply for the future. This problem of carburetting blue water gas is of recognized national importance. Among the interesting possibilities is the long recorded reaction between carbon monoxide and hydrogen, both constituents of blue water gas, to produce methane, an ideal enrichment gas.

Then we should be interested in the production of synthetic rubber as consumers of more than six hundred million pounds, or 70 per cent. of the world's production, all imported and exacting an annual tribute close to a half billion dollars. Synthetic rubber is more than a dream, for it has been not only realized in the laboratory, but during the war was produced in large quantities in Germany. It can be made from a certain class of hydrocarbons, known as the diolefines, through a process called polymerization. Now these diolefines are not in the radium class for scarcity. In fact, they are produced in large quantities in every petroleum refinery in this country. They are present in crude cracked naphtha, where they are unwelcome and a source of trouble to the refiner who must dispose of them, and his method is by destroying them. They are reported to form gums and generally stick up the valves of your automobile. In order to remove these bodies, the petroleum industry annually suffers a loss close to ninety million gallons of motor fuel valued at nine million dollars, and incidentally destroys diolefines equivalent to a substantial proportion of our national requirement for rubber.

Here are two typical research problems such as comprise the frontiers of our industries. Instead of a guerilla attack, involving casual work here, duplication there, and general chaos, the great opportunity of organized research, ably directed, sufficiently financed and sustained in prosecution, is evident. Such an enterprise requires imagination, courage and faith in its sponsors. It is a most attractive speculation.

Organized industrial research is a speculation which is of growing appeal to those who are endowed with the vision to comprehend its possibilities and the means to act. The creation of new industries through a research accomplishment is one phase of this appeal.

Confronting new discoveries and advances in every branch of science, the task and obligation of the worker in the field of industrial research is to make these more immediately available for service. Given the necessary financial support, he can speed up and more energy can be concentrated on our industrial frontiers.

Del Mar spoke to the point when he said, "Industrial research is accelerated experience."

RESEARCH, THE PRIME MOVER OF INDUSTRY[1]

By MAURICE HOLLAND

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THERE is a time-worn illustration which strikes harder now than when first uttered, because the faith of the man of science has been so overwhelmingly justified. A member of the government to whom Michael Faraday was showing a new experiment in electricity said slightingly, "Very curious, but of what use is it?" "By and by, my lord," replied Faraday, "you may tax it." This prophecy was made nearly a hundred years ago.

In 1925 one of the largest manufacturing concerns in the electrical industry paid an income tax of seven and a quarter million dollars. What factors are responsible for this "time lag," in this instance, one hundred years from the discovery in pure science research to mass production in industry? How are the milestones in progress marked?

They are marked definitely. The successive stages in the development may be designated thus: First, discovery in pure science research; second, applied science; third, invention; fourth, industrial research; fifth, industrial application; sixth, standardization, and seventh, mass production. This is the "cycle of research." It is not measured in volume of production or dollar dividends but in terms of time. The speeding up of the period of the cycle—the reduction to a minimum of the "time lag" from the discovery of the principle to mass production is the criterion of the effectiveness of scientific research as an industrial aid.

Let us trace the development of the electrical industry and determine to what extent it conforms to the pattern of the "research cycle." The "time lag" in each successive stage is emphasized in this chronological outline.

THE ELECTRICAL INDUSTRY

The first stage in the cycle is represented by the discovery of current electricity by Volta in 1779. Working in "applied science," Sturgeon utilized this observation and constructed the first electromagnets in 1825.

Entering the period of "invention," Faraday, based on his investigations in pure science, constructed, in 1831, the first dynamo, which later was destined to "electrify" the world.

The period of "industrial research" is associated with the theoretical work of the physicists Gauss, Weber, Rowland and Hopkinson.

"Engineering development" is linked with the name of Siemens, and the products of the combined labors, theoretical and practical, with the shunt-wound, the gramme and drum armatures, as well as the multi-polar machines, while it remained for Edison to make the "industrial application" by establishing the first central station in 1882 at Pearl Street, New York City.

With the dawn of the era of industrial research as an accepted industrial tool, in 1890 a new generation of engineers, well versed in physics and mathe-

[1] Paper presented before Section K—American Association for the Advancement of Science—Kansas City, Missouri, December 29, 1925.

matics, who mastered the use of alternating current, and to whom belongs the credit for the rapid development of transformers, synchronous and induction motors, and the huge alternators of the present day. The first alternating current line operated at 2,000 volts. Increases in transmission voltage have gone up at the rate of about 9,000 volts a year. About 1900, 44,000 volt lines were in service; in 1912, 150,000; and at present 220,000 volt lines are in service. Every step of the way has been paved by research.

In forty-three years the electrical industry has grown from a single plant to one having a book value of twenty-five billion dollars and a generating capacity of 20,000,000 H.P.

The electrical industry is representative of those comparatively young industries which have taken full advantage of research. Three of the largest concerns in this industry—the General Electric, the Westinghouse Electric and Manufacturing and the American Telephone and Telegraph Companies are together spending about one fifth of the total amount appropriated for industrial research in the United States.

It may seem paradoxical, but is nevertheless true that the older industries have been the last to recognize the importance and value of research work.

To bring this out, in sharp relief, let us trace in chronological outline the development of one of the oldest industries, the textile industry.

The Textile Industry

While the spinning and weaving of textile fabrics is one of the oldest arts known to man, the tools used and methods generally followed only one hundred and fifty to two hundred years ago had changed little, if any, since the days of King Tut. Until 1730 all yarn was spun by hand from slivers or rovings. In 1738 Paul patented a new method of spinning with the aid of rollers. Davenpart, in 1763, took out the first patent granted in the United States for his spinning and carding machines. During the years 1773–1775 Arkwright developed the automatic carding machine and also introduced the factory system into the textile industry. In 1792, the year of Whitney's invention, this country exported 189,316 pounds. In 1812, 237 patents were granted American inventors. A year later, the first mill in the world, in which the whole process of cotton manufacturing from spinning to weaving, was carried on by power. In 1816 Ira Draper patented his self-acting loom temples and in 1823 Arnold invented the compound gear. In 1828 J. Thorpe introduced Crompton's "ring frame," and Kay simplified the work on heavy fabrics by making a shuttle with a handle. Kay's son, Robert, produced the "drop box" by which it became possible to work many different kinds of cross threads into the same fabric. In 1837 William Crompton took out his first patent for a loom to weave figured patterns. About 1845 Arkwright established the factory system in England, while Slater did so in the United States. Lucius Knowles, in 1873, secured protection for the idea which is regarded as the basis of the present-day Knowles loom. The invention of the fancy-dress-goods loom was completed by George F. Hutchins in 1883. In 1895 various mills throughout the country adopted the Northrop loom, which revolutionized weaving as completely as the power loom.

Thus far the development of this industry might be classified an art rather than an industry, as judged by modern standards. But finally it has succumbed to the research idea introduced within the last twenty-five years. The textile industry, steeped in tradition and prejudice, based on technology handed down from generation to generation, has at last called upon the aid of science in the solution of its technical problems.

A group of textile manufacturers in New England now support a cooperative research organization known as the Cot-

ton Research Company which, in its comparatively short period of operation, conclusively proved the value of research and the adaptability of its universal application to all types of industries. In England, under the government subsidy plan for the support of cooperative research, the Cotton Research Association was established in Didsbury, a suburb of Manchester. The entrance of applied science even at this late date, in a field which for centuries has been the backbone of industrial England, has done much to dispel the fallacy, existent for generations, that it was the "air of Lancashire which produced a superior grade of cotton goods."

The first director of research in one of the largest private laboratories was a physicist. To-day this association is supported by 95 per cent. of the producing industry, employs eighty-seven scientists, including specialists in every field of science basic to the industry, from botanists who study the various species of cotton plants, physicists who investigate the physical properties of the fiber, chemists who analyze its constituent elements, mechanical engineers who apply the scientific principles to the manufacturing processes, and finally industrialists who are responsible for the application of the results of research to full-scale commercial production.

The annual appropriation available for research, which is raised through an assessment prorated on the basis of the number of spindles in the mills of each member-company, is approximately $225,000 a year.

It is interesting to note that when the last word was written in textile history with the introduction of the Northrop loom in 1895, this same year marked the birth of an industry in this country which has come to take the first place in importance and size of all contemporary industries as listed in the recent U. S. Department of Commerce Census of Manufacturers.

The Automobile Industry

The automobile industry in America rests on the foundation of a patent granted to Selden, in 1895, which covered the principle of using an explosion engine in a road vehicle. The honor of being the first to make a successful gasoline automobile in America belongs to Charles B. Duryea. In 1900 R. E. Olds made the first type gasoline automobile. As late as 1903 Ford made the first Ford car of the present day.

The motor-car industry has taken full advantage of the possibilities of research organization. There are the General Motors Research Corporation laboratories serving as the centralized organization for that important group, the very considerable research organization of the Packard Motor Car Company, and the completely equipped automotive research units attached to the Studebaker and Dodge plants. The recently established research laboratory of the Ford Motor Company is a model in construction, design and equipment—a symbol of the important place which research occupies in that efficient organization.

There are four industries which have been developed from their basic invention to an important place in our present industrial organization, in a period of less than fifty years.

These are electric illumination, radio, electrochemical, and telephone. There is in each striking evidence of the interrelation of the "cycle of research" with the various stages in the development of each industry.

Electrical Illumination

Tracing the electrical illumination industry in briefest outline, we see the various steps pass in rapid succession, including the discovery of the principle of heating platinum wire to incandescence by Sir Humphry Davy in 1800; the experimental work on a carbon conductor in an evacuated glass bulb by the American, Starr, in 1841; the first suc-

cessful incandescent lamp developed simultaneously by Edison and Swan in 1878; the products of industrial research, the tantalum lamp in 1902 and tungsten drawn wire in 1906, which has now been adopted as the universal form; mass production is reflected in the figures of ninety million dollars paid for incandescent lamps in 1924. No stronger evidence of the benefits of research can be presented than the single fact that the cost of a given amount of light to-day is about 5 per cent. of what it was in 1880.

The Radio Industry

This lusty youngster cries out for recognition in raucous challenge among his elders, although he was ushered into the world but fifty-five years ago. His parentage was unquestionably scientific, since he was created from the stuff that science is made of—the involved mathematical formulas put forth by the English physicist Maxwell. But Maxwell's assertion that the ether of space transmits peculiar electric waves attracted little attention until, in 1890, Hertz startled the scientific world by demonstrating the truth of Maxwell's theory. Five years later Marconi gave the invention to the world in the first actual wireless telegraph and after a lapse of but a decade more wireless telephony was successfully tried for transatlantic communication by the technical staff of a great commercial company.

During the World War spectacular maneuvers were executed by squadrons of planes flying in formation on orders given from the ground by a wireless telephone. Within the last two years this device has been used for communication between ships at sea and commercial telephone stations. To-day radio is a successful connecting link with ships, with aircraft, across oceans and for reaching large groups of people as in broadcasting.

The development of radio for the automatic guiding of airplanes, torpedoes and even watercraft promises to have a spectacular and perhaps a very important future.

Electrochemical Industry

Aluminum was discovered in Germany in 1828 by Wohler. In 1855 it cost ninety dollars a pound. By 1886 it had fallen to twelve dollars. The American Castner process brought the price in 1889 down to four dollars per pound. Hall, in America, and Hersult, simultaneously in Europe, discovered that cryolite fused readily at a moderate temperature and when so fused dissolved alumina as boiling water dissolves sugar, and to the extent of more than 25 per cent.

The pure science or discovery period represented by Wohler was followed by the labors of others in applied research, which brought the development to the period of invention. In 1895 the manufacture of aluminum was started at Niagara Falls under the Hall patents. In 1911 the market price of the metal was twenty-two cents and the total annual production forty million pounds. By 1919 the production of aluminum had increased to two hundred thousand tons or ten times the amount in 1911. This latter statement indicates industrial application and suggests mass production.

One of the most important of the electrochemical industries is electrolytic refining of copper. To-day one of the forms in which the metal is most prominently available is electrolytic copper.

Electrolytic methods are also proving useful in the refining of precious metals. The extraction and refining of gold and silver, electrolytically, is assuming important proportions.

The problem of recovering tin from tin cans and other scrap is now carried out electrolytically. About 90 per cent. of tin in scrap is recovered in a form 99 per cent. pure, rivalling our old friend Ivory soap, which is claimed to be 99.41 per cent. pure. Electrolytic iron, which is used in considerable amounts in the manufacture of certain types of telephone equipment, also is very pure.

The Telephone

A classic illustration of research as an industry builder and the servant of man is the telephone. In tracing the development of this industry, three points are to be emphasized. First, that in the short span of forty-seven years, growth has expanded from a single telephone to a single concern which is rated as the largest industrial corporation in the world. Second that the research laboratories of the American Telephone and Telegraph Company, spending approximately ten million dollars a year for research, has been the largest single factor in this development. Third point is that its inception and subsequent growth was paralleled with the development of industrial research in the United States.

Forty-seven years ago there was one telephone in the world, the instrument which Bell invented. To-day there are sixteen million in the United States alone. At the time of its invention there were two telephone employees; to-day there are three hundred and fifty thousand. Forty-seven years ago the world's entire telephone plant could be held in the hand of one man. To-day with over sixteen million instruments in this country alone we have twenty-one thousand central offices, twenty-five million miles of wire and a total plant investment of two billion dollars. Last year the American Telephone system carried eighteen billion communications over a total distance of forty-five billion miles. Assuming that these messages were carried by separate messengers it would require the services of six million people, at a cost of ten billion dollars, to perform a task which the telephone company handles expeditiously with three hundred and fifty thousand employees at only a fraction of the cost. A few milestones in the path of research in this gigantic development may briefly be cited. The first paper insulated telephone cable contained fifty pairs of wires. Through concentrated development these were increased to one hundred in 1892; four hundred in 1900; and in 1912 to nine hundred. Two years later a twelve hundred pair cable was successfully developed, and even more recently fifteen hundred pair, or three thousand wires. This particular development has yielded a saving in the Bell system alone of one hundred million dollars.

Under the pressure of an increase in the price of tin used as a 3 per cent. admixture in lead cable sheath, a new sheath using 1 per cent. antimony was developed. In ten years this new formula has resulted in a saving of six million dollars. A new contact metal, used in relays and switches, to take the place of platinum, has paid a dividend of thirteen million dollars since 1916. Through the application of the phantom circuit principle to four hundred thousand miles of line, a saving of the order of eighty million dollars has been made. Without the use of loading coils, developed by research, it would have been necessary to resort to larger copper wires involving an additional expenditure of one hundred million dollars. Now we can see why in the face of advancing costs among the few remaining things that a nickel will buy are a car ride, the *Saturday Evening Post* and a telephone call.

Even in this sketchy outline of these industries there appears unmistakable evidence of the successive stages in the research cycle from the discovery in pure science to mass production in industry. It is significant that the time lag in these industries cited has been reduced to something less than fifty years. Now let us inquire into the nature of those factors which have been responsible for this phenomenal growth. The second fundamental principle is the relation of research to specific industries. This relation is quite definitely governed by five factors:

First, the rate of growth and develop-

ment of the industry itself. It is obvious that the older industries have to combat tradition and prejudice and continue with little change in processes because of a technology which is the accumulated experience of generations and which has become crystallized. A rapidly expanding industry, with processes in state of flux, with personnel coming to it with a fresh point of view is in the very nature of things progressive. As an example of one of the oldest industries, consider the fisheries, in which present-day methods of operation are fundamentally the same as two thousand years ago, as described in the incident on the Sea of Galilee, in which the fishermen were ordered to lower their nets for the catch.

Parenthetically, there is evidence that even the fisheries industry may enlist the cooperation of applied science in the solution of their technical problems. Within the past few months the division of engineering and industrial research has answered a request from the Middle Atlantic Fisheries Association for assistance in the organization of research in that field.

Second, the inherent technical nature of the industry. Obviously such industries as electric illumination, radio, electrochemistry, telephone and others of this general character were virtually born in the research laboratory—the seed of research is deeply rooted in the foundation of the industry itself.

Third, the character and number of technical personnel employed in an industry. A large cordage manufacturer in the middle west recently employed as a factory superintendent a man who had been trained as a chemical engineer and imbued with the research idea. On his first inspection trip through the plant he complained that the processes were archaic and immediately formulated plans for a research program and laboratory through the intermediary of a technical college in a nearby town.

Fourth, the position in foreign trade. As an illustration, out of the economic pressure of the World War a new industry was created for the manufacture of optical glass in this country. We had been entirely dependent on Germany as a source of supply for this commodity previous to that time.

Fifth, the character of processes and the present research facilities available to the industry. With these factors in mind, it is not difficult to understand the rapid development of the four industries last mentioned, since each encompasses from three to five of them. All are inherently technical in character, they employ large numbers of scientific and technical personnel, their growth has been rapid, their processes depend on scientific control rather than manual skill and they have developed during the era of industrial research.

While research is a primary factor in reducing the time lag in the cycle of development of an industry, it does even more than this: it not only affords technical superiority in competition between industries and provides an advantage to individual concerns within an industry which is competing with their fellows, but it is a dominating force in the present industrial age, since it creates industries and even destroys them—destroys in that it revolutionizes present processes, invents new ones and therefore may be the basic reason for the creation of a new industry or the specialized subdivision of the same.

The introduction of Methanol, the German process for the manufacture of wood alcohol, aroused fears in the wood alcohol industry of this country that an industry representing a capital investment of one hundred million dollars would be totally destroyed.

The reference to the Bell System Research Laboratories, the largest connected with a private company anywhere in the world, brings to mind an even more recent example.

The Victor Talking Machine Company had a business so highly profitable and so well organized that dividends on its common stock averaged more than forty-two dollars a share for eleven years, to which in 1922 was added a 600 per cent. stock dividend. Meanwhile research has developed the radio and the Victor Company has passed its dividend. You have all, no doubt, heard the new Orthophonic Victrola, but how many of you know that this new device is a byproduct resulting from fundamental research in the range and quality of the human voice, which was being studied for the amplification and improvement in quality and tone for long distance telephony in the Bell System Research Laboratories. Speaking technically, science created one device, and its byproducts, applied in another field, gave a new lease on life commercially to an industry which was threatened with destruction.

The third fundamental principle in the relation of research to industry is the period of the introduction of research and the accelerated development which follows. This effect has been described in several younger industries. What happens when research is undertaken in older industries? Let us take an extreme case—one of the oldest industries in recorded history.

The Iron and Steel Industry

Possibly the oldest piece of iron known was found in the great Egyptian pyramid "Gizeh," and is at least six thousand years old. Of primitive furnaces, one type, still used in remote parts, was successfully developed by the Germans in the Middle Ages, and is known as the "Catalan Furnace," because it was used in Catalonia, Spain.

In 1617 an Englishman, Dudd Dudley, was the first man to melt iron in a blast furnace with coke instead of charcoal. Abraham Darby in 1713 put Dudley's idea into practical form. In 1726 Corts introduced the rolling mill for rolling sheet iron. Huntsman, in 1740, devised the crucible process of making high-grade steel. In 1783 Corts developed grooved rolls for rolling iron bars and rods, and one year later he built the first reverberatory furnace. In 1828 Nielson further reduced fuel waste by heating the air of the blast. In 1856 Bessemer devised the process which completely revolutionized the steel industry. In 1857 William Kelly patented his converter, and in 1860 Siemens perfected the regenerative gas furnace. In 1893 the "Seven Merritt Brothers" turned over the greatest ore producer in the world. In 1898 Professor Sauveur, of Harvard, put forward his first iron carbide diagram, showing the eutectoid transformations and their relations to the heat treatment of steel. Note the period of introduction of research and the subsequent rapid development. In 1900 the development of high-speed steel by Taylor and White was first demonstrated in Paris. Vanadium and high-speed steel was introduced in America by Dr. J. A. Mathews, the present research director of one of our large steel concerns. Others were experimenting with it in Europe, but vanadium high-speed steel was first put on the market by an American company.

To indicate the development of the basic processes in steel making, in 1909 only .06 per cent. of steel was made by the electric process, while .4 per cent. was crucible. To-day less than .2 per cent is crucible.

The phenomenal growth of the steel industry is indicated by the fact that the production has risen to seven hundred pounds per capita in 1920 and one thousand pounds per capita in 1925.

This brief outline shows that the steel industry for hundreds, if not, thousands of years, was an art, and that within less than fifty years it has felt the influence of research and has experienced a greater development in that period than all the centuries preceding.

Now having briefly traced the historical development of five industries which have reduced the time lag from basic invention to full scale industrial application to less than fifty years, and have set up for comparison two industries which had their beginnings in earliest recorded history, what conclusions can we draw?

It is conceded that, in tracing the single threads in the pattern of our industrial fabric, warp, the body, is dependent for its strength on basic technology and technical improvement. The weft is an equally important component and may be influenced by such factors as economic pressure, commercial exploitation and even political and social forces.

From the record of the industries which have as the cornerstone in their foundations the invention of the incandescent lamp by Edison and Swan in 1878, the telephone of Bell in the same year, the first central station in 1882, the industrial application of Hall's patents in 1895, Selden's patents in the same year and Marconi's radio as late as 1900, we may submit the following:

First, all five industries—the radio, electrochemical, illumination, telephone and motor car—are inherently technical in nature, employ technical personnel, have had a rapid development and growth and production processes which are dependent upon technical knowledge rather than skill. These selected industries then include four of the five factors which I mention earlier which govern the relation of research to specific industries. Second, all five closely follow the successive stages in the research cycle. Third, at least two—electrochemistry and radio—were virtually created by research. Two of these industries—the automobile and the electrical—have taken first and third places, respectively, in importance and size among all industries in less than fifty years—certainly a minimum in time lag even in these days of high speed, automatic and mass production.

The telephone, although by certain standards not classified as an industry, deserves individual recognition. Emerging as an invention from the experiments of Bell, its individual development and application has produced the largest single industrial concern in the world. This enviable position has been attained almost wholly through the results of research. The security of its position based on a monopoly has been maintained by the backing of the largest research organization in existence attached to a private enterprise. In a thirteen-story building entirely devoted to research, the Bell System Research Laboratories employ over three thousand people. These include scientists, engineers and technicians, all engaged in the solution of technical problems arising in the field of communication.

Here the time lag in the research cycle is reduced to the absolute minimum, since within this organization, personnel, equipment and supplies are available in each stage of the complete cycle from "discovery in pure science" to industrial application and the preparation for mass production. This does not mean, of course, that inventions are made and reduced to practice over-night. Long and careful tests must be made of new devices in actual service.

There remains but one of the first groups of industries to consider, namely, electrical illumination, since the development of this industry in its major aspects is a parallel to that of the telephone. Although the initial impetus may be credited to Edison's first successful incandescent lamp, the wide-spread industrial application in the present universal form dates from the drawn tungsten wire of the pure science research laboratories of the General Electric Company. The development of the present Mazda lamp, as it is known, was carried through the complete research cycle under the supervision of this research unit. Even today the laboratory exercises a quality

supervision over the manufacturing units through a system of scoring based on defects. The cost of present-day lighting speaks volumes in testimony of research as an industrial aid.

Of the two industries in the second group—the textile and iron and steel industries—even in the comparison of the bare outline of their development it is apparent that it has taken centuries to accomplish in them what has been done with the aid of research in decades in the first group.

The iron and steel and textile industries until comparatively recent times were arts as distinguished from scientific industries dependent upon skill rather than technical knowledge, employing artisans rather than technicians, and were handicapped by tradition, prejudice and human frailties handed down from generation to generation. At no point, except within very recent years, did science touch the course of their evolution. Processes and tools were the inventions of skilled practical artisans and mechanics. A detailed analysis will indicate that they do not contain a single element of the factors which encourage the development or utilization of research.

We may have been so intent upon examining the details of our picture that we have overlooked the importance of the development period of industry as a whole in the last century. The boring mill of Wilkinson was perfected in 1774 and used to bore the cylinders for Watts steam engine; Maudsley, during the period of 1771–1831, developed the slide rest for metal-working, screw-cutting tools, and laid the basis for the lathe, the planer and the plotter.

Of this period, Roe in "English and American Tool Builders," says, "By 1850 mechanical equipment was substantially what it is to-day; in fact, most of this change came in a generation, the period from 1800 to 1840."

Within the last forty years this new factor, industrial research, has considerably altered the foundations of the industrial structure. Generally speaking, there are three types of industries or businesses.

Measured by modern standards each depends to a greater or lesser degree upon research. The most successful industry or business from the standpoint of earnings rests upon a monopoly. A patent is a seventeen-year monopoly granted the inventor for his ingenuity and work. Even professional men of outstanding eminence, who command large fees because of their prestige or skill, or because they can do something no one else is thought to be able to do, are monopolists in a sense.

Next in strength is the industry or business enterprise founded on strategic position, the only factory of its kind in the district, a store on the corner of two main thoroughfares, the warehouses built on the waterfront of a city which grew. Such businesses are less certain profit producers. They are more dependent upon chance, efficient management and upon service rendered.

The third type is formed on service and popular appeal, such as a department store, a hotel operating under highly competitive conditions. In this type of business, effective management, novel publicity and popularity are vital necessities.

Research to insure the safety of invested capital is essential to the first type of industry. Research to maintain a strategic position is essential in the second class, and research to secure every advantage in the fight for survival is vital to the third class.

The extent to which research has developed as a recognized and valued industrial aid in about forty years is indicated by this statistical data. We are spending approximately \$100,000,000 a year for industrial research in the United States. The government, with its many scientific technical bureaus and research agencies, attached to practically every department, is

spending approximately one third of this amount, while industry is matching dollars for research two to one for the government expenditures. A recent survey in research indicated that the federal government was engaged in five hundred and fifty-three separate cooperative projects, three hundred and sixty of which were research involving altogether eleven hundred cooperative undertakings. The federal agencies engaged in research include some twenty-three bureaus. There are nearly six hundred industrial research laboratories in the United States exclusive of government and university research agencies. Fifteen individual industrial companies from which reports are available are spending in the aggregate for research between twenty and twenty-five million dollars. Some thirty trade associations are spending approximately twelve million a year. Research in the universities, institutes and technical colleges have assumed considerable proportions especially in such well-known ones as Carnegie Institution, Massachusetts Institute of Technology, University of Illinois, Purdue, Mellon Institute, Cornell and many others.

How important this is may be judged from the "Waste in Industry" report of the American Engineering Council, which placed the average waste in our industries at 49 per cent., 70 per cent. of this being chargeable to management.

The lack of appreciation of the importance and value of research compared to other recognized industrial aids such as advertising, statistics, publicity, etc., is indicated by the fact that we are spending eleven dollars per capita for advertising, five dollars for jewelry, twenty-seven dollars for joy riding, pleasure resorts, etc., eleven dollars for candy, twenty-one dollars for automobiles and parties, and eighty-seven cents per capita for research.

The reader's own judgment may strike the balance between the service and return of these items with which we are familiar, in comparison with that from research, which several reputable industrial companies have authoritatively stated as from five to ten to one for the investment involved.

A Department of Commerce expert has figured the annual loss in waste in American industry at thirty billion dollars. It would seem that the expenditure of one third of 1 per cent. of this amount for research is absolutely inadequate.

When we consider that half the population of the United States carries average life insurance of $1,300, it would seem that American industry can afford considerably to increase its premium in insurance against waste and ignorance. Annual insurance premiums are paid for such remotely removed catastrophes as tornado, windstorm and cyclone, to the amount of twenty-six million dollars, and combined marine insurance of approximately sixty-four million dollars—three items which total the approximate amount spent to improve the basic technology of our industries.

Several industrial leaders recently have sounded a warning of the foreign competition that America will have to face in the next few years. Tariff walls or other political or commercial devices will not prevail against the technical superiority of European nations which long have had research solidly entrenched in their industrial organization.

In England, the British government, through their subsidy plan, has appropriated five million pounds to encourage the establishment of cooperative research associations in various industries. At present there are twenty-six active research associations operating under this plan in which the industries match pound for pound the appropriations of the government.

In France the government allows industrial concerns to deduct from their income tax a percentage of the funds appropriated for research. A bill which recently passed the Chamber of Depu-

ties provides a tax of five centimes on each one hundred francs paid in salaries. It is estimated that seven hundred thousand dollars annually will be raised by this means for the support of scientific research laboratories.

In Germany industrial research amounts to almost a creed. Its supremacy there was heralded throughout the world before the war. It made a lasting impression during that struggle, and is at the moment being organized for competition in the world of trade.

Are we prepared to meet this foreign industrial competition? What specific proof can be presented which will vitalize the broad generalities previously mentioned with concrete realities? What are some of the outstanding research achievements of representative laboratories? To what extent has the "time lag" in the "cycle of research" been minimized?

A cross-section of the more recent research projects, together with an indication of the period of the cycle from discovery or conception to commercial production, is suggested in these answers to my inquiry. From the General Electric Research Laboratories:

Loud Speaker

1922 preliminary study of factors; 1923 resulted in crystallization of certain ideas for loud speaker designs and later in the same year development of present type began. Laboratory and engineering development was completed by the spring of this year. Quantity production was begun early this fall.

From the report of A. D. Little research organization this development in fuel research is quoted:

New Vaporphase Process for cracking Petroleum

Three and a half years ago the general conception of the process came to them, since then the research has passed from the small laboratory scale to large-scale laboratory operation, then to a semi-commercial plant with a daily output capacity of eight barrels of oil, then to one of twenty-five barrels, and finally to the design and construction of a three hundred and fifty barrel unit, which they expect to bring into operation next January.

The General Motors Research Corporation added this evidence of research in paint:

Duco

1920 DuPont people learned how to increase the total solids of duco many times without making the material too thick to apply. 1921 they brought their problem to General Motors and they helped with commercialization of the conception. 1923 first cars finished with Duco were put on the market by Oakland.

In electrical research the Westinghouse Electric and Manufacturing Company cited this project:

Lightning Arrestor

Early in 1921 one of the engineer physicists conceived the idea of using a certain electrical phenomenon as the basis of a lightning arrestor. Preliminary tests were made and his theory was established. Research work was undertaken, preliminary construction and tests were made and experimental field units were put out in the fall of 1921. 1923 commercial production was undertaken. 1924–1925 quantity production.

The director of research for the E. I. du Pont de Nemours Company covered several phases of chemical research and explosives:

Improvements made and New Developments

Safety explosives for use in coal mines to prevent explosions due to ignition of coal dust and mine gases have been developed, and du Pont Company has developed a complete series of non-freezing high explosives, which have been a very great advance in the art owing to the large number of accidents which were caused in former times by the thawing of high explosives containing nitroglycerine. Most recent development in smokeless powder manufacture is a progressive burning powder for shotgun uses which has the quality of giving higher velocities with lower pressures and higher shot loads. Du Pont Company has also developed in the last few years some very important seed disinfectants which seem not only to have the property of destroying disease germs on the seed, but also aid the propagation and the growth of plants in their early life.

The Bell System Research Laboratories reported somewhat more generally to this effect:

Of the products of the research and development work of these laboratories there may be mentioned: machine switching telephone developments; multiplex transmission—telephonic and telegraphic by carrier currents; the development of various types of loud speakers including the most recent cone; of phonograph methods of recording and reproducing; apparatus for the study of speech by harmonic analysis, and of hearing by audiometers, and of relief of partial deafness by audiphones; applications of these developments to the amplification of heart sounds and to their phonographic recording; the entire group of contributions of the laboratories in the way of elements and systems for radio; and various electronic appliances like the cathode-ray oscillograph and the ionization manometer. All of these have reached standardized forms and mass production within recent years.

This glimpse through the door of a few representative research laboratories is reassuring. Here is conclusive evidence that our research organization is geared up to the present speed of industrial progress, and here are several instances in which the "time lag" has been reduced to a period of less than five years.

There remains but one question to be answered. Does research pay dividends?

To answer that question is to consider the relative growth, development and earning capacity of representative industrial corporations as reflected in income taxes paid by the first ten concerns reporting at the last period.

Among the first ten names which are synonymous with large and completely organized research departments, are the Ford Motor Car, American Telephone and Telegraph, United States Steel Corporation, General Electric, General Motors, Standard Oil, New York Central, Consolidated Gas, Union Pacific and Reynolds Tobacco Company.

Seven of the first ten have as an essential part of their production units research laboratories of international reputation. The total income tax paid by these ten concerns is approximately seventy-five million dollars, or three quarters of the aggregate expenditures for research in the United States.

In these figures we see the final appraisal of the value of research, a real measure of industrial progress, the ultimate stage in our research cycle, an indicator of the speed at which the main rotor in the prime mover is turning.

To act as sponsor in organizing the resources of science for the solution of the technical problems of industry is in effect a broad statement of the purposes of the Division of Engineering and Industrial Research of the National Research Council.

Since another function of the division is concerned with engineering, we may perhaps through that experience be able to insert a gear in the engines of industrial progress which will still further reduce the "time lag."

This increment of acceleration in the "research cycle" will be transmitted through the whole train of economic, industrial and commercial mechanisms, since they are geared directly to "Research—the Prime Mover of Industry."

Author's Note: Grateful acknowledgment is made to the authors of "Profitable Science in Industry" which was freely used as reference. Also to the Research Laboratories mentioned in this paper.

PSYCHOLOGICAL METHODS TO PROMOTE HIGHWAY SAFETY

By J. McKEEN CATTELL

PRESIDENT OF THE PSYCHOLOGICAL CORPORATION

JUST forty years ago there were published by me the first psychological measurements of individual differences, based on experiments made at the Johns Hopkins University and the University of Leipzig. These experiments were of two kinds. On the one side exact measurements were made of the time of the reaction of different individuals to various signals and situations, including the effects of fatigue and distraction. On the other side series of tests were used in which with pencil and paper the individual met certain situations, and the time and correctness of the answers determined what is now usually called "general intelligence." These experiments were made in the laboratory ten years before the invention of the automobile and are one of many examples of how scientific research may ultimately prove to be of practical use. The driver of a car needs to react quickly and correctly to the situations that he meets on the road and without disturbance from unforeseen happenings or emotional excitement. He must have a certain amount of common sense and intelligence, in order to be able to drive without causing inconvenience or risking injury to others.

We need to use psychological methods to determine how well an individual can drive a car and in so far as possible to predict how well he will be able to learn by practice. It is not nearly so dangerous and difficult as was once supposed; but it is obvious that in ability to drive individuals differ greatly, partly by varying natural aptitudes, partly by amount and kind of experience. Those who can not drive on the highways without inconvenience and risk to others should not be permitted there. If an individual has only moderate aptitude he should take this into consideration in deciding whether to buy a car, to drive it under difficult conditions, to take out his wife and children. Unless he has more than average natural ability, he should not take up motor car driving as a calling.

Psychological tests that can be made in three hours predict whether or not a boy is likely to do well in college. For a considerable percentage of those examined the writer is prepared to pay the entire college expenses if the student gets the degree, in case the father will pay an equal sum in case he fails. If each boy and girl were tested at the age of sixteen, it would be possible to predict with a reasonable degree of accuracy where he would stand among all automobilists who had, say, driven 10,000 miles, after he himself had driven that far. He might do better or worse than the test predicted, but on the average the prediction would be correct within certain limits. Such a test would only take the time and have the cost of half a day at school; it would be far more useful as a factor in education, apart from the valuable information that it would give.

Every ability is to a certain extent special and at the same time has factors common to other abilities. We can

make a threefold classification that is useful. There is the logical ability to reason and deal with abstractions, which can be measured by the way in which an individual handles numbers and words. There is the objective ability to deal with things, machines and concrete situations, which can be measured by suitable methods and apparatus. Lastly, there is the social ability to get on well with other people, which has only recently been taken up by psychologists, but in which we expect rapid progress in the near future. Thus it has been found recently by the Psychological Corporation that more than seventy per cent. of typists applying for a given position would cheat when given the opportunity without apparent chance of detection.

The man who drives his own car requires a certain minimum abstract intelligence, but perhaps only enough to stand above the lowest 10 per cent. of the population. He requires relatively more mechanical ability, though less than was formerly supposed. The question of social ability is still open, but it is important. Proper regard, not only of the rights, but also for the convenience and welfare of others, is a factor scarcely considered. A driver may have ample intelligence and unusual skill, but may be inconsiderate and careless, or may take chances to an extent that makes him unfit to use the public highway.

Licenses for Drivers

A license should be required for every driver of a car, if only as a means of identification, but the examination should be simple and easy to administer. Special attention should, however, be given to professional drivers, to those suffering from disabilities which may interfere with safe driving, and to those who have had accidents or have been convicted of serious offenses against the motor laws.

These are recommendations made by a sub-committee, of which the writer is chairman, to the Committee on Causes of Accidents of the National Conference on Street and Highway Safety arranged by the Secretary of Commerce. They have been adopted by the committee and will be brought before the conference at its approaching meeting. It is proposed that applicants for licenses to operate motor vehicles on the public streets and highways shall be divided into four groups who shall be given examinations as follows:

Group A. Applicants for licenses to drive private cars who shall be given an examination that will yield the best results in a limited time and shall be comparable in all jurisdictions.

Group B. Public chauffeurs, including drivers of taxi-cabs, busses, trucks and emergency vehicles, who shall be given a more difficult and searching examination.

Group C. Applicants suffering from some disability such as defective eyesight or hearing, loss of limb, old age, illiteracy, a record of insanity or conviction of crime, who shall be given a special examination.

Group D. Those who have been responsible for accidents resulting in personal injury or considerable property damage, or who have been convicted of serious offense under the laws governing the use of motor vehicles, who shall be given a thorough examination before their licenses are permanently renewed.

The subject is of such general scientific and practical importance that it may be desirable to review the grounds for these recommendations and the psychological methods that the writer regards it as desirable to use in order to eliminate the incompetent driver of motor cars and thus to increase the safety of the highways.

Applicants for Licenses to Drive Private Cars

Owing to the fact that the number who apply for licenses to operate motor vehicles is very large, it is necessary that the examination be as simple as possible. It seems to be desirable, therefore,

that in addition to information on the application form the examination shall consist only of an information test and a road test.

The application form should be drawn up with care and made the same in all jurisdictions. It should record the age, sex, place of birth and legal residence of the applicant, and—for purposes of identification—the height, weight and color of eyes and hair. For the latter purpose consideration might be given to requiring in addition to the signature a photograph or a fingerprint impression. The applicant should be asked whether he has been responsible for any accident causing personal injury or involving damage to the property of others to the apparent amount of $10, and whether he has been fined or imprisoned for any offense against the motor laws or involving the use of motor vehicles. If he answers in the affirmative he should be referred to Group D. When a motorist is arrested for any cause the records should be examined and any one who has committed perjury on his application blank should be prosecuted. The only other question recommended is whether the applicant has any defect that seriously interferes with driving a car. If he answers yes, he should be transferred to Group C for a special examination. If he answers no and is later arrested and proved to have a serious defect he should be prosecuted for perjury.

Questions should be avoided that can not or will not be answered correctly by the applicant. Thus if normal eyesight and hearing are required, the tests, which can be made in ten minutes but require expert knowledge on the part of the examiner, should be made. Applicants can not answer questions such as are asked in some jurisdictions; almost every one has eyesight or hearing defective to some extent, and an answer "yes" or "no" conveys no information useful in deciding whether a license shall be granted. The applicant should be watched for possible disabilities in the road test and in case he exhibits or gives indications that he has any serious defect he should be transferred to Group C for a special examination. It is futile to ask whether the applicant uses intoxicants or drugs. It is not useful to inquire the number of years or the number of miles the applicant has driven, for it is likely to be answered incorrectly; if he passes the tests in a satisfactory manner the smaller the mileage he has driven the more likely he is to become a competent driver. A similar situation obtains in reference to a requirement that the applicant shall have driven at least a hundred miles under guidance. It would require an expert examiner to evaluate such a factor as this. It should be a credit if he passes a good road test after having driven only a few miles, a demerit if he passes a poor test after a large mileage.

The information test should consist of printed questions designed to discover the applicant's knowledge of the laws and traffic regulations which he is expected to obey, his judgment in operating a car, and his ability to recognize difficult, dangerous or illegal situations. There should be a uniform test that will be of equal difficulty at all times and at all places. Such a test prevents favoritism and determines just where the applicant stands among those who are examined.

In addition to the written information test there should be an individual road test which should also be standardized so that it could be reported, *e.g.*, that an applicant stands in the upper fifth or lower tenth of all applicants. It is also important to avoid favoritism or different methods of examination. For a standardized examination a testing yard would be desirable, laid out so that the applicant would drive and turn within

definitely marked lines, stop and start on an incline of 15 per cent., avoid obstacles, follow road signs and park within a given area.

Accidents undoubtedly occur through the use of different cars by the same driver and the gear shifts and other mechanisms should be standardized for all cars, by legal enactment if that proves to be necessary. It is, however, probably not useful that a license be given to drive one make of car only, as a competent driver of one car can learn to operate another in a short time, and unnecessary and irritating restrictions that are likely to be violated should be avoided. It seems unnecessary that questions be asked concerning the mechanism of the car or repairs on the road, as these do not seriously affect highway safety.

It is not feasible that there be an examination each year for the renewal of the license. In time and money of the applicant and of the examiner it would cost over a hundred million dollars a year to reexamine twenty million motorists. There should, however, be an application for renewal each year and the applicant should be required to report any accident causing personal injury or property damage amounting to $10 in which he has been involved, and any fine or conviction under the traffic laws. Motorists who stand in the lower tenth or fifth of those passed in the examinations might be given a temporary license for one year and be re-examined before renewal.

Information concerning traffic rules is so easily acquired for an examination and so readily forgotten afterwards, the practice and ability needed to operate a car in a simple test are so small and so useless in an emergency, and the difficulty of securing competence and fairness in the examination so considerable, that it is quite possible that it would be desirable to give consideration to waiving a formal examination and only requiring the applicant to declare under oath that he had studied the laws and regulations and is competent to drive a car on the road, the statement perhaps being affirmed by two witnesses. In the future a thorough physical and psychological examination for a license may become desirable, but it appears that there is no more danger in operating a car than in driving a team of horses under the same traffic conditions. In general no restrictions should be placed on individual liberty which are not required for the welfare of others, but each should be held strictly accountable for the results of his actions. Strict examination should, however, be required for public chauffeurs, applicants having defects or handicaps, and those involved in accidents or convicted of offenses.

Professional Drivers

There should be a more thorough and difficult examination before a license is granted to professional drivers. These include drivers of taxi-cabs, delivery wagons, busses and trucks; chauffeurs in the public service and private chauffeurs when a special license is required; drivers of school busses or cars; drivers of emergency vehicles, such as hospital ambulances, postoffice wagons, police wagons and fire patrols. These drivers are fewer in number and a careful examination is consequently feasible. They continually use streets and roads maintained by taxation and needed by pedestrians and by other drivers. They may have right of way, the waiving of a speed limit and other privileges. They may operate vehicles especially liable to harm the roads and to cause personal injuries or property damage. The state has a certain responsibility such as it undertakes in licensing physicians, pharmacists or barbers.

It might be assumed that the public services and large corporations would arrange in their own interest for special examinations and this is now being taken up for the Postoffice Department and by some taxi-cab companies. But in most cases the number of drivers concerned is too small to warrant special examinations by the employer and some corporations would prefer a public examination in view of their relations to their employees. It is also the case that in a matter that so greatly concerns the public welfare the state should maintain its authority. For example, a taxi-cab company that has special examinations which show that accidents are more than twice as frequent for those who do not pass them none the less waives the examination when there are not sufficient applicants.

Character of Examination

For professional drivers the information blank should be more complete and the written examination and road tests more exacting. The applicant should be required to give full information concerning his record and history, his habits and defects, and should be held strictly accountable for the correctness of his replies. In the written examination and in the road test, ordinary knowledge and skill should be assumed and a thorough examination given to ascertain that the applicant is expert in knowledge of laws and regulations and in ability to meet conditions of traffic with special reference to the vehicle that he will operate and the condition under which it will be used.

In addition there should be physical and psychological examinations. Eyesight and hearing should be tested and probably color blindness. It is not recommended that color blindness, from which about one man in twenty-five and one woman in a hundred suffers, should be a disqualification for the ordinary license, but in the case of professional chauffeurs it should be given careful consideration. The same situation holds for imperfect hearing, high blood pressure, liability to fainting fits and other disabilities which may be the cause of accidents.

It is further recommended that there be a psychological examination of general intelligence which, however, can be combined with the information and operating tests. Those of such low intelligence that they would be classed as morons and would not be accepted as army recruits should in the interest of public safety not be allowed to be public chauffeurs. There should also be a psychological test of quickness and accuracy of response to the situations that the driver will meet, including his presence of mind under disturbing conditions. Such tests can be made while the vehicle is being operated, but they can be made more accurately, quickly and with reference to ability rather than to practice with special apparatus and laboratory methods. Carefulness also can be determined. If there is a testing yard the driver's skill can be determined by requiring him to drive as quickly as he can ten times around a circle or oval, keeping within a marked track. One section of the track can be oiled so that skidding must be avoided. If the driver is quick and at the same time keeps within the lines he is a good operator, if he is both slow and inaccurate he is incompetent, if he is quick but crosses the lines frequently, he is careless or reckless, a quality to which special attention should be given. Similar results can be obtained from tests with laboratory apparatus. There are other qualifications that professional chauffeurs should have, such as the efficient and economical use of the car and ability to make repairs on the road, which mainly concern the employer but are not irrelevant to public safety.

The importance to the public safety and the responsibility assumed by the state in granting licenses to public chauffeurs may ultimately make it desirable to require as a prerequisite a course in a special school which grants a diploma based on a definite course of instruction. In that case a temporary license might be granted subject only to annual renewal after re-examination until the chauffeur has obtained a professional training.

Handicapped Applicants

There are various defects and handicaps which interfere with driving and the safety of the road. They may be comparatively slight but always present, as hardness of hearing; or unlikely to occur but serious if they do, as an epileptic fit or a stroke of apoplexy. Those suffering from defects of this character are not fit to be professional chauffeurs, but it does not follow that they should be forbidden to drive their own cars under suitable conditions. During the war recruits were rejected if they were shortsighted, even though in spite of this defect many of them would have made better soldiers than one half of those enlisted.

In some jurisdictions deafness or the loss of a limb debars an applicant from a license. It can, however, be argued that the greater care likely to be exercised by a man who is deaf will more than compensate for this defect; his liability to accidents can only be determined by a careful statistical investigation. In any case a man who is deaf and is at the same time of high intelligence and an expert operator is a safer driver than one with normal hearing, but standing in the inferior group to which licenses are granted.

The proper method, as indeed in granting any license after a careful examination, is to have a scale of merits and demerits. Thus 100 should mean that a man is in the first one per cent. of all adults in his intelligence, skill and other qualifications as a driver. If it is decided after scientific investigation and review that the least competent thirty per cent. of the adult population (including defectives, criminals, the feeble-minded, the illiterate, the aged, etc.) are unfit to drive on the public roads, then a percentile grade of 31 would be the lowest qualifying for a license. These grades have what is technically known as a probable error which can be determined. It might be in the neighborhood of ten places low in the scale which would mean that the chances are about one in four that the applicant graded 31 is among the 20 per cent. of the population least competent to operate a car and that the chances are nearly even that he is worse than the 30 per cent. fixed as the lower limit for licenses. It is these considerations that have led to the suggestion that those who stand low in an examination shall be given a license for one year only and then be required to repeat the examination.

This point percentile system can be used to special advantage in the case of the defective and handicapped groups. For example, if it is guessed now or determined later that 20 points, adjusted from the middle of the scale, is the handicap of a man who has lost his left arm, then if he stands in the upper half of those passed in his other qualifications he should be granted a license, if he stands in the lower quarter it should be refused. The quantitative deduction for any handicap can be estimated approximately or determined by scientific experiments. Thus if total blindness or technical insanity are assigned a demerit of 80 graded points, no one having one of these defects could obtain a license whatever his other merits might be.

If an applicant is so illiterate that he

can not read road signs he is refused a license in some jurisdictions, but consideration has scarcely been given to those who are not illiterate but who can not read English. Those who can not read or understand the written examination in the ordinary test might be referred to Group C where they would be given a more thorough examination and their handicap duly weighted.

An insane asylum or recent prison record, drunkenness, or liability to a disease such as epilepsy should be regarded as serious handicaps and licenses should rarely be granted to those who suffer from them. This can be adjusted by the system of merits. For example, recent conviction of a serious crime such as robbery or rape with the use of an automobile should give a demerit of 80 or 100 graded points which would be prohibitive. Conviction some years previously of a crime such as forgery would give a smaller demerit.

The Age Handicap

The age handicap deserves special consideration. The committee on uniform laws recommends a limit not lower than sixteen years and in some jurisdictions the limit is higher. We do not at present know whether or not a boy of seventeen or of fifteen who passes an examination as good as that of a man of fifty is or is not more likely to have an accident or to violate the laws and regulations, but this could be determined by adequate experiments or statistics. If a boy of seventeen or of fifteen is not more likely, or even if he is only slightly more likely, than an adult to be involved in an accident he should with the approval of his legal guardian be given a license on the same conditions as others. It is undesirable to have useless restrictions that are likely to be violated, and the earlier an individual learns to drive the better driver he will probably be in later life. Thus the granting of licenses at a comparatively early age may lessen accidents in the future. We are concerned with the psychological and mental age of a youth rather than with his calendar age. A boy of sixteen or seventeen may be as competent with a car and in all the affairs of life as the average boy of eighteen. If the lower limit is eighteen a license to drive under special conditions at an earlier age should be granted as it now is in New York state. It would also seem reasonable that a youth under the legal age might with the approval of his guardian be referred to Group C and be given a special examination for mental age and qualifications to drive.

The older ages have not hitherto been a serious problem, because owing to the recentness of the automobile and especially of its extensive use there are but few old drivers. We have as yet but little scientific knowledge regarding the situation after middle life, but it is evident that after a certain age a driver will become less competent and may become altogether incompetent. It may be desirable that after an individual reaches the age of sixty his license should not be automatically renewed, but that he should be referred to Group C for a special examination.

Drivers involved in Accidents or Violation of the Law

It appears probable that most accidents causing personal injury or property damage are due to a small proportion of all motorists, as are also a majority of infractions of laws and regulations. It consequently appears to be highly desirable that those involved in accidents or convicted of other than trivial offenses should be required to undergo a special examination for competency, such as is recommended for professional chauffeurs and handicapped classes, with such further examination of the individual and of the circumstances as may be desirable. If the accident or offense is serious the license should be suspended until the examina-

tion has been held and a thorough investigation has been made of the causes and circumstances of the accident or offense; if the accident or offense is not serious, the license should be continued provisionally for 30 days, or until the examination and investigation have taken place.

It may be that such an examination should be required only after a second accident or offense, especially if the first is not serious, but it is difficult to obtain the record of previous accidents, and no one who is competent and careful should object to such an examination. It is urgently needed in the interest of public safety for those who are incompetent or reckless. The time required for an examination and the payment of its cost would be a reasonable penalty and would be an extremely useful and quite feasible preventive measure, leading all drivers to take greater care to avoid possible accidents or serious infringements of the law, such as reckless speeding, which may be the cause of accidents. An incidental advantage of a thorough examination of those involved in accidents and of the circumstances is that it is the best way to obtain knowledge concerning the causes of accidents and the means of preventing them.

General Considerations

The regulation of motor traffic on the public streets and highways is a problem of the utmost complexity and importance. While statistics are not altogether adequate it appears that there are about 22,000 deaths and 700,000 personal injuries a year caused by motor vehicles. The damage to property is very large. The number of warnings, arrests and convictions, sometimes only for violation of regulations adopted for general convenience, but frequently for offenses, putting life, person and property in jeopardy, is unknown, but is very large. About ninety per cent. of all accidents with motor vehicles are due to the human factor. It is reasonable to estimate that deaths, injuries, property damage and offenses might be reduced to one half and perhaps to one fourth, if the best methods for licensing drivers of motor vehicles and for controlling motor traffic were adopted and these methods were perfected by further investigation.

It should be remembered that the pleasure, advantage and economic value of motor vehicles are enormous, the service that they render being of use to practically every one. Due largely to improved methods of control and systems of licenses, deaths and accidents are increasing more slowly than the total traffic. In fifty-seven cities with an aggregate population of about twenty-seven million, nearly one fourth the total population of the country, there were reported 4,827 automobile fatalities in 1923, 4,992 in 1924. Deaths and disablements from motor vehicles are small compared with those from influenza and colds, and there are no compensating advantages in the case of the colds.

Laws and regulations should only be made when on the one hand the benefits are greater than the drawbacks, and on the other hand when they are supported and likely to be enforced by general public sentiment. Owing to the vast importance and the newness of the subject arrangements should be made for thorough scientific inquiry and investigation continuing over a period of years. This should be under the auspices of the Department of Commerce which has initiated the work, with funds appropriated by the federal government for the purpose, given by public-spirited associations, foundations and individuals, or contributed by makers of cars, insurance companies and others who profit from the use of motor vehicles under the most favorable conditions.

AROUND THE WORLD IN A DAYLIGHT DAY: A PROBLEM IN FLIGHT[1]

By Dr. CHARLES H. T. TOWNSEND

ITAQUAQUECETUBA, ESTADO DE SAO PAULO, BRAZIL

WILL the possibility suggested in this title ever become reality? It seems probable that this question may be answered in the affirmative. The airplane practically owes its existence to a study of the problem of flight among the lower animals. May not a more complete study of such flight, therefore, result in attaining whatever speed is an accomplished fact among them? There seems to be no mechanical reason why this hope should not be realized.

What is the swiftest flight known among the lower animals? Bird flight has posed as the usual model in air studies, but we must evidently turn to the insects and among them to the flies if we are to look for a demonstration of the highest rate of speed. The swiftness of flight of certain birds seems almost without rival, but certain flies exceed even their remarkable speed.

The flies of a muscoid group, represented by the genus *Cephenemyia* of North America and Europe, but also including several other genera, evidently hold the world's record for high speed in flight. This is the more strange since these flies take no nourishment whatever in the fly stage. All the feeding of *Cephenemyia* and its congeners is done in the larval stages, the larvae being parasitic within the nasal passages and other head or throat cavities of various species of deer and allied ruminants. It is apparent from this fact that *these flies carry a tremendous supply of stored power in extremely reduced bulk and weight.*

Swiftness of flight is a prime requisite in the economy of these flies, enabling the females not only to scour immense tracts of country in their search for suitable host animals, but also to overtake them when found and deposit larvae in their nostrils. The male *Cephenemyia* flies frequent high and bare mountain tops; the females usually frequent the haunts of their hosts and always so after fertilization. They have much the appearance of bumblebees in both size, form and color, but are of a slighter build. They live many weeks in the fly stage and can doubtless maintain their swift flight for hours at a time. It has so far proved impossible to capture them in full motion. The few specimens known in museums have been either taken while alighted and warming themselves in the sun, captured during minimum activity at temperatures below the optimum or reared from larvae secured from the host animals.

Can the speed attained by *Cephenemyia* in flight be calculated with any degree of accuracy? The writer has endeavored to do this, having repeatedly witnessed what he considers both males and females of this genus in full flight. In extended flight their passing is of such an incredible swiftness that one is utterly unable to initiate any movement whatever toward capture before they vanished from sight. Form is not sensed by the eye as they pass, but merely a blur or streak of color and only a fleet-

[1] Read before the Third Pan-American Scientific Congress at Lima, Peru.

ing glimpse of that. It may be safely estimated, in the opinion of the writer, who has given much thought to the subject, that *these flies attain a speed upward of 400 yards per second.*

If it were possible to drive an airplane at this speed for seventeen hours at a clip, the feat suggested in our title could be accomplished. Let us verify this assertion, for it is worth while to examine this matter, however stupendous it may appear. The distance around the earth on the 40th parallel is 13,855 miles. At slightly less than 400 yards per second, we should accomplish 815 miles per hour or 13,855 miles in seventeen hours, on a nonstop trip from early dawn to late twilight of a summer's day.

Setting out from New York at 4 A. M., we could take *coffee* over Omaha, *breakfast* over Reno, *tiffin* over Peking, *tea* over Constantinople, and *dinner* over Madrid, while arrival in New York at 9 P. M. would complete the circuit. Here is the tentative approximate schedule:

rate of speed by discovering all the mechanical principles involved. Is not such an investigation well worth trial?

Increased strength and elasticity of materials with reduced bulk and weight of power are the problems now confronting aircraft evolution. Heavier-than-air machines can evolve no farther until these essential problems are solved. Their solution has already been attained in *Cephenemyia*, as has also the solution of the high speed problem, hence a full study of the manner of these solutions is all-important. The airplane, in its present stage of evolution, is capable of making the above 40th parallel circuit of the earth in a trifle over fifty-five hours, provided the present highest average rate of speed (250 miles per hour) can be continuously maintained for that length of time. Multiply by three the highest speed yet attained (266 miles per hour) and we approximate *Cephenemyia*, with the above daylight-day circuit in sight.

But speeds grow gradually and before

New York to	Miles		A. M. Leave 4	Meals	Distances between points		Hours between points	
Omaha	815		5	Coffee	815	miles	—1	hour
Reno	1,630		6	Breakfast	815	"	1	"
Peking	6,520		12 M.	Tiffin	4,890	"	6	hours
Constantinople	9,780		4 P. M.	Tea	3,260	"	4	"
Madrid	11,003		5:30	Dinner	1,223	"	1½	"
New York	13,855	Arr.	9 P. M.		2,852	"	3½	"

Such a feat as the above would cause Jules Verne's illustrious shade to blanch and pale. Even his fantastic imagination could scarcely conceive such a spectacular outcome as here suggested. But the facts are already written in insect economy and why may we not copy them? Quite probable it is that an exhaustive study of the *Cephenemyia* mechanism may point the way to the realization of this almost inconceivable

we reach the *Cephenemyia* mark we shall register many lower speeds by the way. Suppose we merely increase by three fourths the U. S. Navy record of 266 miles per hour recently made by A. J. William in a Curtiss hydroplane. Even this would allow us to encircle the earth in a daylight day if we fly farther north. The distance around the earth on the 60th parallel is only 8,312 miles, the accomplishment of which would re-

quire a speed of only 226 yards per second or 462 miles per hour maintained for eighteen hours. Starting from Juneau or Dawson at 3:30 A. M., this circuit could be made via Nome, Siberian points, Petrograd, Reykjavik and Hudson Bay back to starting point by 9:30 P. M. This, a less ambitious mark than that afforded by the 40th parallel course, we may confidently expect to realize in a few more years if we apply to airplane development the results to be secured from a study of flight in flies.

It is certain that what has been attained by animals in the way of locomotion can be equalled if not exceeded by machines. All the work-performing feats accomplished by animals rest solely, in the last analysis, on purely mechanical principles. Thus the whole matter is practically a problem in mechanics, but in those as yet unknown mechanical principles involved in the structures of *Cephenemyia*[2] and its congeners.

If the actual speed of these flies be only half the estimated, they are well worthy of investigation in the interests of mechanical flight.

[2] For details of *Cephenemyia* in North America and photographs of the flies, see *Journal of the New York Entomological Society*, XXV, pp. 98–105; and XXIII, pl. 11.

BIRD LIFE IN KAMCHATKA[1]

By AUSTIN H. CLARK

SMITHSONIAN INSTITUTION

Kamchatka is a place all of us have heard of, though few of us have been there. We have not been there because it is one of the most difficult places in the world to get to, there being no regular communication between it and other regions. We have heard of it because in school geographies it is commonly given as the typical peninsula. From the northeastern end of Asia it extends in the form of a pointed leaf in a southwesterly direction separating the Sea of Okhotsk from the Bering Sea and the Pacific Ocean. Beyond its southern tip, called Cape Lopatka, a chain of islands called the Kurils runs southwestward to Japan.

Kamchatka has a central backbone of mountains, some of them over fifteen thousand feet in height. Among these mountains, mostly on the eastern side, there are no less than twelve active volcanoes, some of which from time to time break out into violent eruptions, and twenty-six craters.

It gets very cold in winter in Kamchatka. In January the average temperature in the northern part is about 6° below 0°; at the southern end it is about 19° above; and at Petropaulski, the chief town in the southeastern portion, it is about 17° above. The western coast is much more desolate than the eastern and is very considerably colder in the winter, but the snowfall is much heavier in the east than in the west. Toward the south especially the snow often lies so thickly that the natives can not keep reindeer.

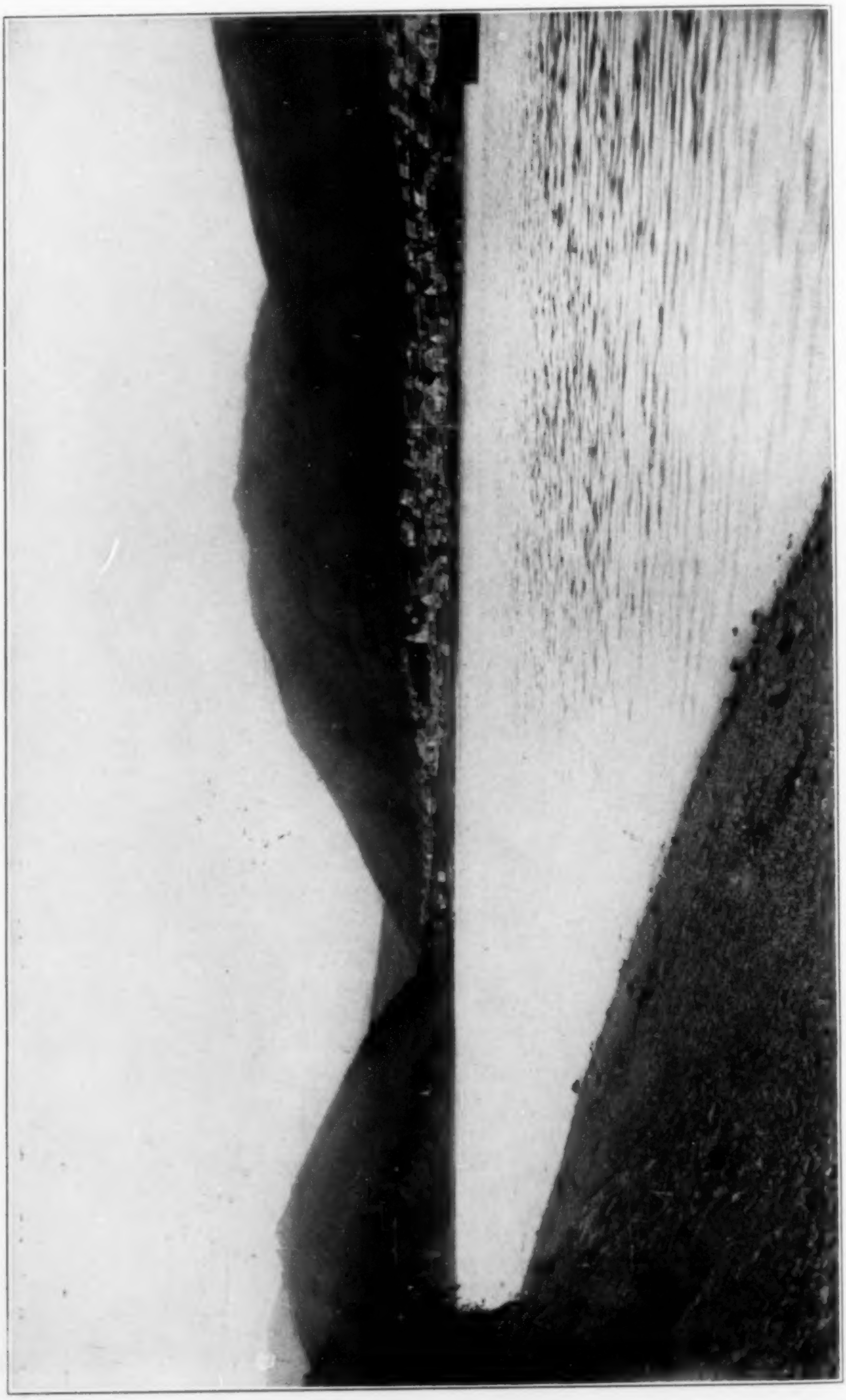
During summer the weather is very uncertain with frequent rains and fogs, but in the center of the peninsula especially there is a large amount of warmth. Vegetation, especially on the volcanic soils, is remarkably luxuriant. In the warmer valleys the grass grows nearly five feet high and may be cut three times a season. In the woods berries, mushrooms and the Martagon lily abound, the bulbs of the last being also used as food by the natives.

For such a large region the population of Kamchatka is very small, and there are few towns of any size. Other than Russians the people are chiefly Kamchadales. They speak a curious language, the sound of which has been compared to that of water gurgling out of a narrow mouthed jug.

One's ideas of any region are often profoundly influenced by first impressions. I reached Petropaulski from Bering Island in the Commander group after having spent nearly a month in the bleak and desolate Aleutian chain where the sun is almost never seen, where drizzling rain or fog or sleet is the usual thing in summer, where the higher land is always more or less snow covered, and where no trees of any kind can grow, though in the warmer places in the lowlands there is sometimes found a wealth of flowers which is quite surprising. In steaming up Avacha Bay toward Petropaulski in calm and perfect summer weather the sight of the pretty wooded hills about the town, the broad meadows, and the great snow-covered mountains in the distance, combined with the songs of hundreds of birds all about, produced a very deep impression and at the time I

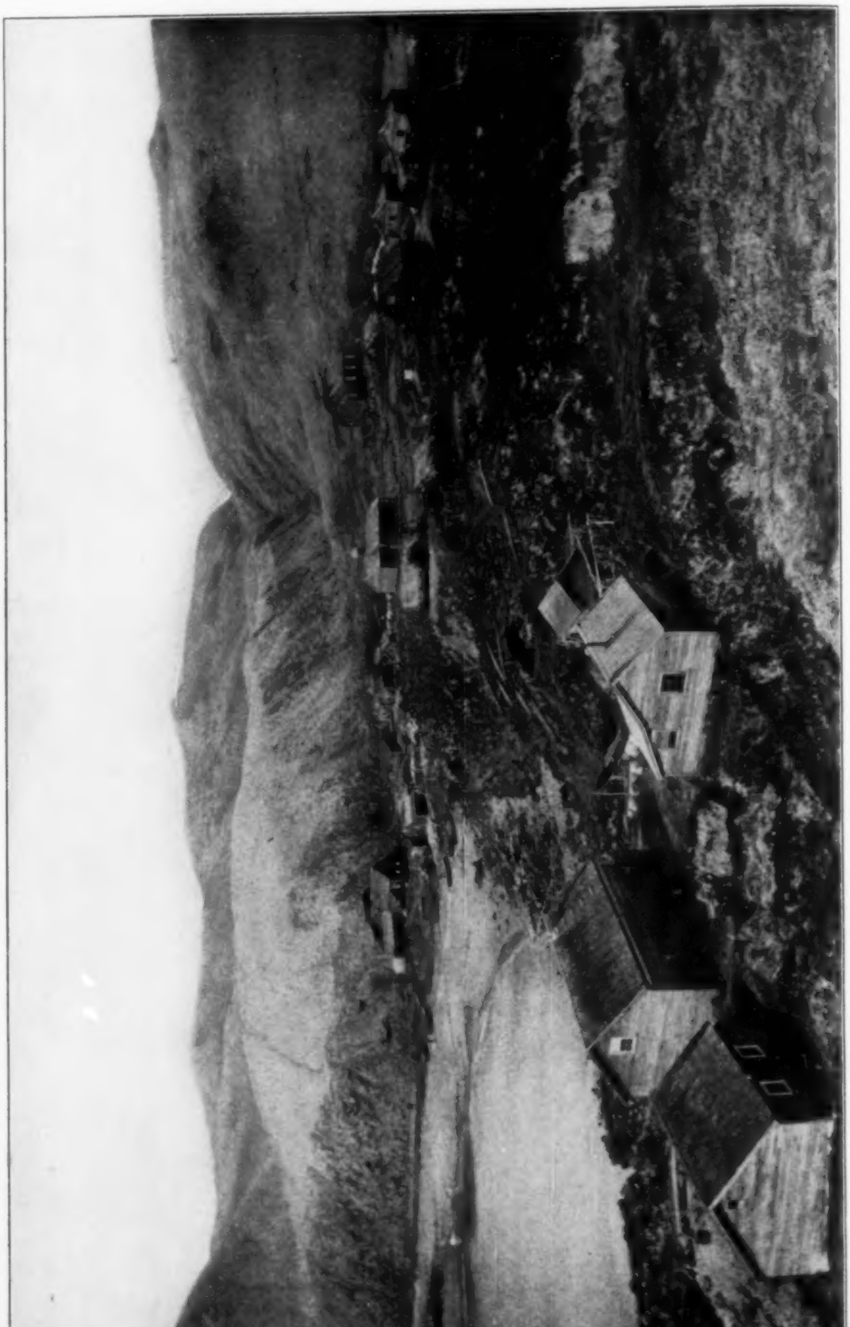
[1] One of a series of Radio Nature Talks from the National Zoological Park, Smithsonian Institution, broadcasted from Station WRC, Washington, January 23, 1926. The photographs of Petropavlovsk are furnished by the courtesy of Dr. Leonhard Stejneger; the others by the courtesy of the Bureau of Fisheries.

A NATURAL ARCH IN THE CLIFF ON AMAKNAK ISLAND, NEAR UNALASKA VILLAGE (ILIULIUK). TAKEN IN 1890.



PETROPAVLOVSK, KAMCHATKA, FROM THE OUTER HARBOR. TAKEN IN 1897.

THE INNER AND OUTER HARBOR AT PETROPAVLOVSK, KAMCHATKA, FROM A HILL BEHIND THE TOWN; JUST BEYOND THE MIDDLE OF THE SAND-SPIT CAN BE SEEN THE MONUMENT COMMEMORATING THE LOCAL VICTORY OF THE RUSSIAN FLEET IN THE CRIMEAN WAR. TAKEN IN 1897.



THE VILLAGE AT ATKA. TAKEN IN 1892.

THE VILLAGE AT ATKA. TAKEN IN 1892.

thought there could not anywhere exist a more charming spot than this little town in farthest Siberia. The weather during my stay was perfect, warm and summerlike, with the sun shining almost all the time.

The first bird in Kamchatka to attract attention is the Siberian ruby-throat, sometimes called the Kamchatkan nightingale. This little bird is not remarkable for its coloration, for it is rather plain, nor for its ubiquitousness, for it is quite retiring; but it is remarkable for its most exquisite song. It is abundant about Petropaulski and sings all day long from sunrise to sunset, its song being the most characteristic bird note of the region. It lives especially on hillsides grown up to bushes and in bushy patches in the meadows, keeping usually on or near the ground, and it is very adept at slinking away through the undergrowth if it is alarmed. The song is usually given from some little elevation, as the top of a bush or the lower limbs of a small tree, but often from near the ground.

Next in importance as a songster, and much more often seen, is the Kamchatkan house-finch, which in general habits and song resembles our common purple finch. This bird frequents the hillsides, but keeps to the more open places, the higher branches of the small trees and the tops of the bushes. It is vivacious and restless, never stopping long in any one place.

The last of the really characteristic songsters occurring about the outskirts of the town is the handsome yellow-breasted bunting which is very common, but scarcely equal vocally to the two preceding. It is much like the house-finch in its habits, but it is less active and less familiar. A similar bunting with a white breast is not uncommon, but I did not succeed in identifying its song.

A near relative of the European skylark is common in the grassy meadows, and its fine song is characteristic of the more level country behind Petropaulski.

A very characteristic bird note of this region is the loud clear call of the eastern cuckoo, quite like that of the European bird, though entirely unlike that of any bird we have with us. The call of the cuckoo was heard at all times, and the birds were frequently seen coursing swiftly around the hillsides or the clumps of bushes in the meadows, from their color and their actions looking much like hawks.

One of the most curious of the small birds of this region is the slate-colored bunting. It lives in the densest alder thickets along the banks of the small streams, keeping on or near the ground. In its habits it reminds you of our white-throated or white-crowned sparrows.

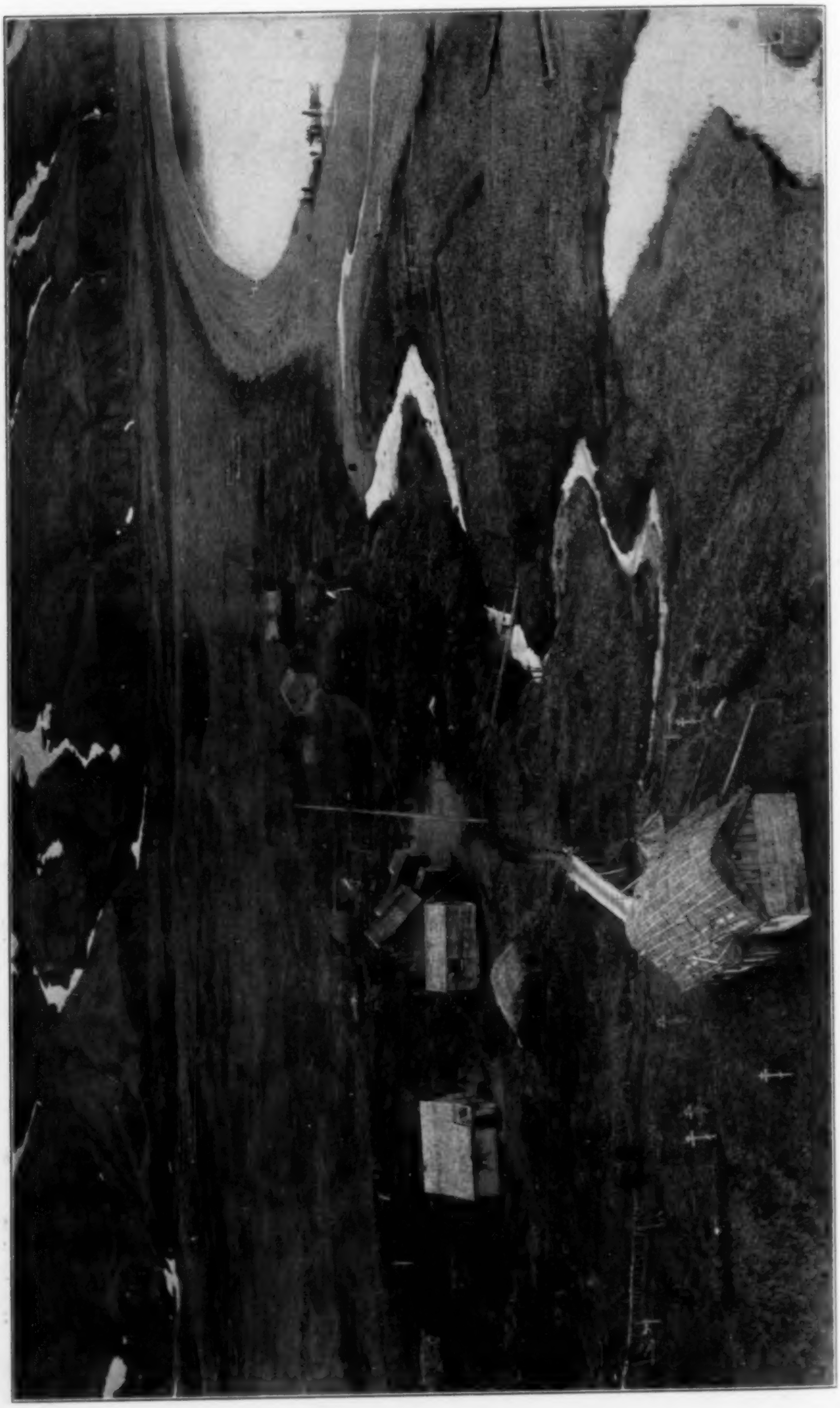
The most conspicuous of the local birds, and one of the handsomest as well, is the Kamchatkan magpie. The magpie is common everywhere, although it is very wary and usually manages to keep well out of gunshot.

Wagtails of two sorts are common. The black-backed Kamchatkan wagtail frequents the seashore, especially the rocky beaches, while the Kamchatkan yellow wagtail is very common in the grassy lowlands.

Whenever I went near any groves of tall trees I was sure to hear a continuous hooting somewhat resembling that of the barred owl; but when I tried to get close enough to find out what was doing the hooting, it would invariably cease long before I was within range, to be immediately resumed from some distant grove. I suppose the bird was the Siberian hawk owl which is the only owl known from the country.

About the taller trees also the eastern tree pipit was common, its song and actions instantly calling to mind our common ovenbird.

Of the larger birds the eastern carrion crow is numerous and was breeding at the time of my visit. I found a number of nests, none of them, however, accessible. The raven is not uncommon, though I saw but one or two. The osprey is very common, and the large Kamchatkan sea eagle, resembling the bald eagle



THE VILLAGE AT ATTU, ALEUTIAN ISLANDS. THE WHALEBOAT ON THE BEACH IS FROM THE "ALBATROSS." TAKEN IN 1894.

WILD FLOWERS COVERING THE HILLS AT UNALASKA. THE WELL-KNOWN BOTANIST, MR. PAUL C. STANDLEY, SAYS OF THIS PICTURE "THE MOST CONSPICUOUS FLOWER IS THE LUPINE, *Lupinus nootkatensis unalaskensis;* THERE ARE SEVERAL CONSPICUOUS PLANTS OF *Geranium erianthum* AND OF A DAISY WHICH, I SUPPOSE, IS *Erigeron peregrinus;* THE VERY LARGE COMPOUND LEAVES ARE THOSE OF *Heracleum lanatum.*" TAKEN IN 1888–89.

SHISHALDIN VOLCANO, UNIMAK ISLAND, FROM BERING SEA. TAKEN IN 1890.

but with white shoulders and a pointed tail, is frequently seen.

Among the water birds the large slaty-backed gull is the most abundant, occurring everywhere about the seacoast, while the blackheaded gull is very common about the large pond behind the town, and is occasionally seen about the inner harbor.

Along the Kamchatkan coast I missed the immense number of sea birds, especially the puffins, murres and small auks of various kinds, which swarm about the Aleutian Islands. In fact sea birds seemed to be quite uncommon. The tufted puffin, a grotesque chubby little bird, which is perhaps the most characteristic sea bird of the Bering Sea, was fairly common in Avacha Bay, and I saw it frequently down the coast to Cape Lopatka and on the Okhotsk Sea side of Kamchatka as far north as I went. But its numbers could not be compared to those about the western Aleutian or the Commander Islands.

On May 28 we visited the Bogosloff Islands, a group of small volcanic islands north of Atka, one of which was first reported in 1796, a second in 1884, while we were so fortunate as to be the first to discover the third. When we sighted this third island steam was roaring out from fissures and cracks all over it, forming a huge steam cloud which, driven by a strong wind, passed to and over the horizon. In spite of the constant roaring, which could be heard for some miles, the adjacent Castle Island, which was the first to be reported, swarmed with birds. With a glass countless myriads of sea birds could be seen flying about along the shores, over the sea, and to a considerable height over the land. I have never anywhere else seen any approach to the enormous numbers of sea birds which swarmed about this singularly desolate island. We did not dare to go in very near, so I can not say just what these birds were. But on the sea about us were large numbers of tufted puffins, and even more murres, so I judged that these were the birds that chiefly made up the vast numbers seen about the land.

Preeminent among the sea birds of the Kamchatkan coast is the short-tailed albatross. It is not very common here, but I saw it both on the Pacific and on the Okhotsk Sea side of the peninsula. This particular albatross is curious in being very shy and usually keeps well away from ships; or perhaps it simply does not pay any attention to them. You see one in the distance, its white underside showing conspicuously against the gloomy sea, and then in a few minutes it is gone again over the horizon. This is in marked contrast to the habits of the dark brown black-footed albatross so common off our western coast and south of the Aleutian Islands. This bird displays a great interest in ships and will follow them for days, often in numbers. One day about twenty miles southeast of Unalaska I counted twenty-two of them behind the ship where they had collected to examine a large piece of meat that I was trailing in the water. The black-footed albatross, unlike the short-tailed albatross, will not enter the Bering or Okhotsk seas, keeping always to the open Pacific.

Desolate and lonely is the southwest Kamchatkan coast, a barren and uninteresting land, with strange inhabitants singularly forlorn in aspect and loath to speak to strangers in the little Russian that they know. But it was here that we formed the first home contacts we had had for several months, for we most unexpectedly came across two barkentines, the *City of Papeété* and the *S. N. Castle*, both from San Francisco, anchored on the cod banks. These boats were both besieged by scores of fulmar petrels on the watch for scraps.

This formed our last impression of Kamchatka. After a brief examination of the cod banks and the return of our surgeon, whose services were required by both ships to attend some injured men, we turned southwestward and left Kamchatka for the more congenial atmosphere of Japan.

Shishaldin Volcano, Unimak Island, from Bering Sea. Taken in 1890.

ARCHEOLOGY IN THE SOUTHERN STATES[1]

By HENRY B. COLLINS, JR.

U. S. NATIONAL MUSEUM

In many localities of the Mississippi Valley and eastward there may be seen to-day great artificial mounds of earth, piled up by human hands, some of them built many centuries before the coming of the white man. Some of these earthworks are of such magnitude that they are familiar to archeologists everywhere, while many of the smaller ones may not be known beyond their immediate neighborhood. In the south these mounds are the only lasting monuments that have been left behind by the prehistoric inhabitants. They are thus usually the center of interest in any consideration of the archeological problems of this area.

For many years the mounds were a favorite topic of discussion among antiquarians, and various fanciful theories were advanced to account for their origin. The prevailing opinion for a long time was that these mounds were the work of an ancient and mysterious race, entirely distinct from the American Indian. Another explanation was that they had been built by Toltecs or Aztecs, who, after living for some time in the region, were driven southward into Mexico.

Such romantic theories as these held sway for a number of years, and it was not until near the close of the past century that they were finally put at rest by the clear demonstration that most of the mounds were erected by the ancestors of the present Indians, and that some of them, in fact, were constructed by the modern tribes after they had come into contact with the whites. We know to-day that there never was a "race" of mound-builders; the building of mounds was simply a custom that was shared by a number of Indian tribes of different stocks. The most important questions that now await explanation are the origin of the custom of mound-building, the period of construction of the mounds, and the tribal affiliations of their builders.

This information must come mainly from three sources. The first and most important is the evidence furnished by the mounds themselves. While outwardly many of them present much the same appearance, excavation has shown that there are a number of distinct types, which tend to be restricted to certain areas. For instance, the effigy mounds of Wisconsin, with their characteristic animal shapes, were built up in an entirely different manner from the burial mounds of Ohio or the large pyramid-shaped mounds of the southern states. The stone weapons and implements, the pottery and the ornaments that were placed in the mounds by the builders and often the bones of the builders themselves are also found to differ considerably. It is possible, therefore, by comparative study to determine the relation of some particular group of mounds with those of other areas and with the tribes later inhabiting the region.

Secondly, we have the traditions of the modern Indians, which, while they

[1] One of the Smithsonian series of radio talks arranged by Mr. Austin H. Clark; given from Station WRC, Washington, February 11, 1926. The photographs are furnished by courtesy of the Bureau of American Ethnology, Smithsonian Institution.

CAHOKIA, FROM THE EAST, AN OUTSTANDING EXAMPLE OF THE SOUTHERN TYPE OF HABITATION MOUND. THIS MOUND, WHICH IS ABOUT 6 MILES EAST OF ST. LOUIS, MO., IS THE LARGEST PREHISTORIC EARTHWORK IN THE UNITED STATES. IT IS 100 FEET HIGH AND COVERS AN AREA OF ABOUT 16 ACRES. SURROUNDING IT AT ONE TIME WERE MORE THAN 60 OTHER MOUNDS.

can not be relied on entirely, may sometimes afford valuable clues as to their early customs and migrations.

A third source of evidence, and one which is of particular value in the south, is that furnished by the accounts of the early explorers, Spanish, French and English. The earliest and most important of these historical accounts are those left by the chroniclers of the De Soto expedition in 1540, who give numerous descriptions of the Indian villages and of the artificial mounds on which some of the houses stood.

In order that we may more readily understand the conditions under which some of these earth monuments were erected, let us see what one of them reveals upon excavation. As an example I shall select a mound in southwestern Arkansas which was opened some years ago by Mr. Clarence B. Moore. This mound was roughly circular in outline, with a basal diameter of about eighty feet and a height of eleven feet. As the upper layer of soil was removed there were found nine large pits which extended down to about the base of the mound and in the bottom of each pit was a skeleton accompanied by a rich mortuary offering. Extending twelve feet into the undisturbed soil beneath the bottom of the mound was another large pit in which rested the skeleton of an aged male. With this burial there had been placed many pottery vessels and weapons and ornaments of stone and copper, while a thick black layer beneath the bones gave mute evidence of other more perishable material that had long since disappeared.

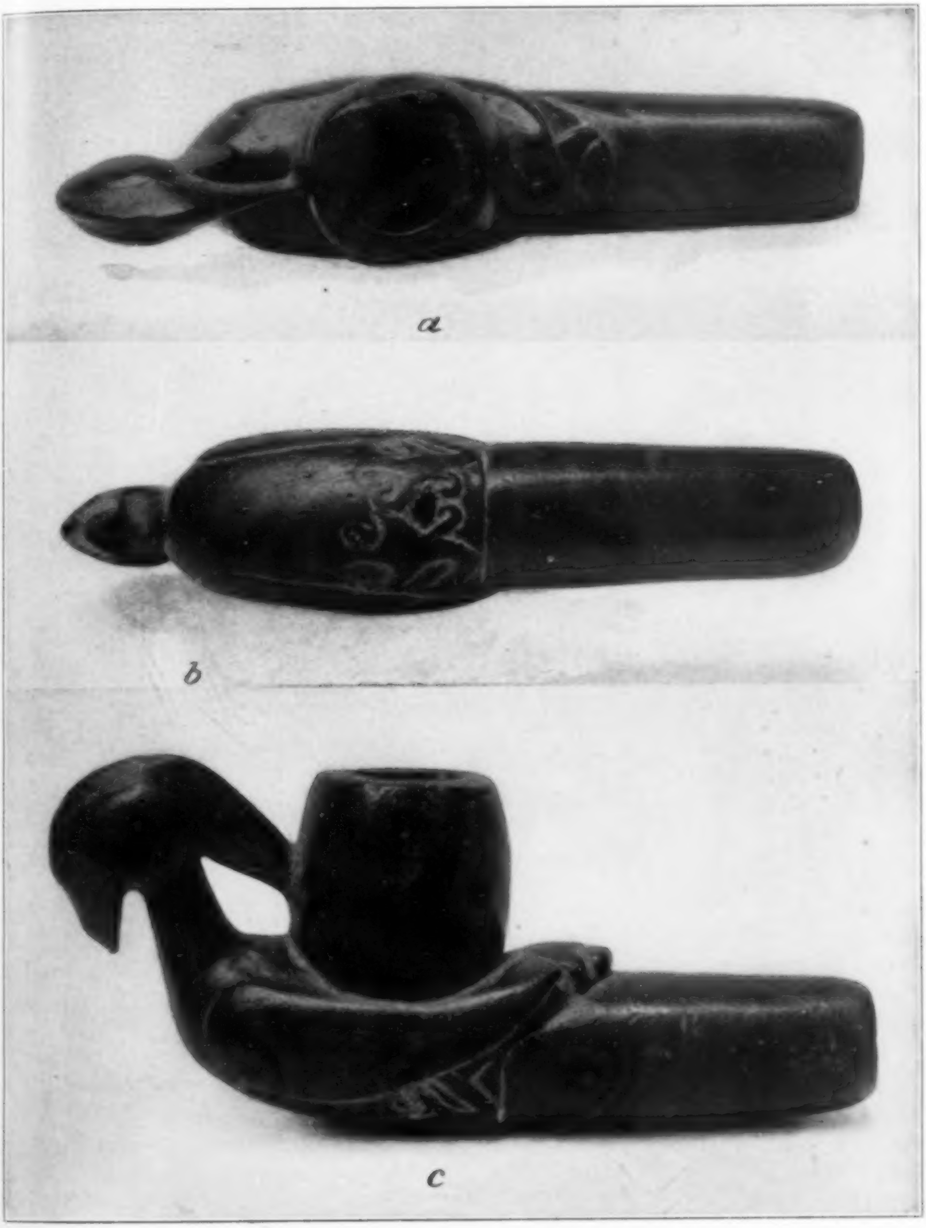
What do these facts reveal as to the identity and customs of the people who constructed the mound? First, it is very evident that the remarkable burial twelve feet beneath the base of the mound was that of a person of some prominence. The great depth of the pit,

which had to be dug laboriously with crude implements of bone and wood, together with the great number of objects deposited therein, are definite indications that the individual thus honored was a man of more than ordinary importance. Moreover, there is every reason to believe that the mound itself was erected as a memorial over this grave. The nine other burials which were made in the mound at a later date were carefully arranged in a circle above the original pit, these upper burials all apparently having been made at one time. It seems very probable, therefore, that here again we have the burial of some important personage, this time along with eight others who had been sacrificed in order that they might accompany him into the spirit world.

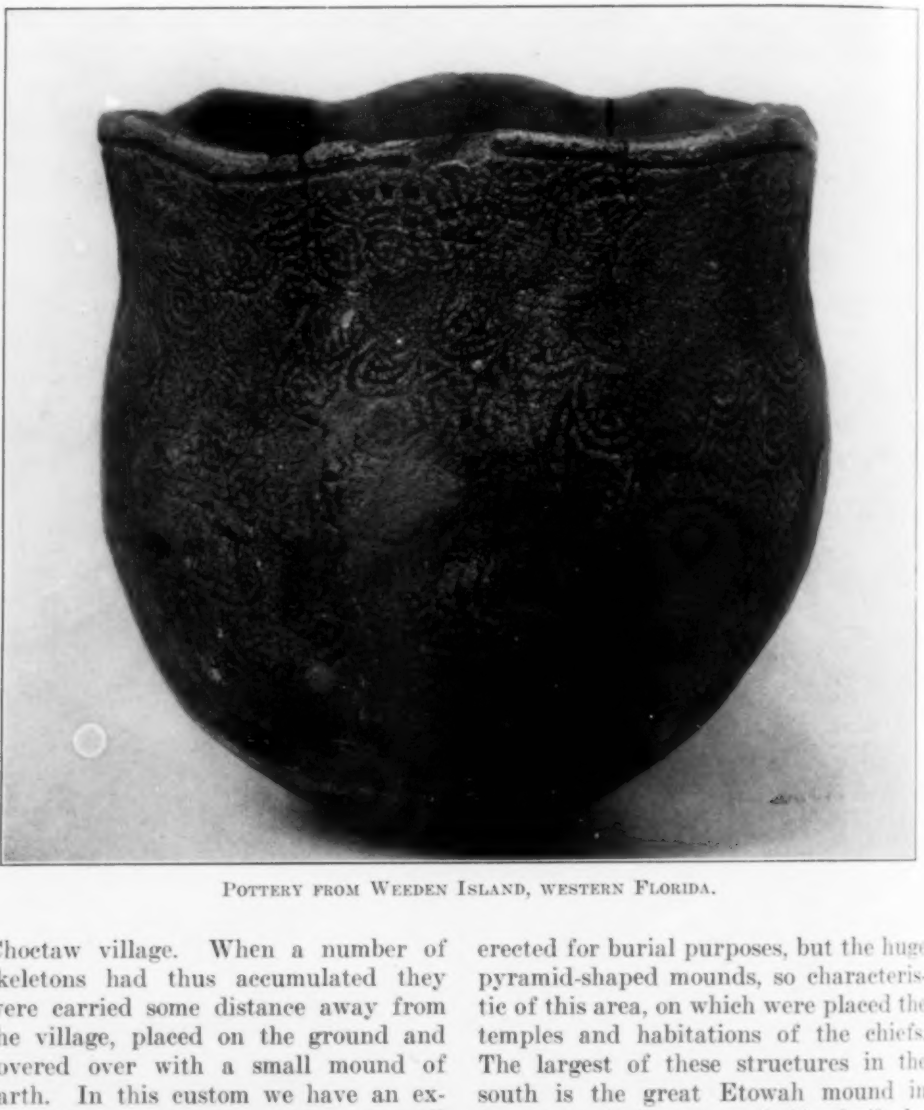
It must not be supposed that either human sacrifice or the existence of a caste system was common among American Indians. On the contrary these features have been observed in only a few instances north of Mexico. The most outstanding example, however, is presented by the Natchez, a tribe living in western Mississippi when first seen by Europeans. This is no great distance from southwestern Arkansas where the mound just described is located, and since the early movements of the Natchez seem to have been from west to east, there is a strong indication that the builders of this particular mound were a people related to the Natchez, a fact that is still further suggested by a similarity in physical type.

The burial customs of the Choctaw, a large tribe formerly living in eastern Mississippi, were different from those of the Natchez, as we know from historical accounts. When one of their number died it was the custom among the Choctaw to place the body on a scaffold or platform erected for the purpose. After remaining exposed for some months it was taken down by the so-called "bone-pickers," whose official duty it was to carefully scrape and clean the bones. These were then placed in cane hampers and deposited in the bone house, one or more of which was to be found in every

NANIH WAIYA, SACRED MOUND OF THE CHOCTAWS, IN WINSTON COUNTY, MISSISSIPPI. ACCORDING TO CHOCTAW TRADITION THE FIRST OF THEIR TRIBE CAME UP FROM THE UNDERWORLD THROUGH THIS MOUND.



STEATITE PIPES FOUND NEAR NASHVILLE, TENN.



POTTERY FROM WEEDEN ISLAND, WESTERN FLORIDA.

Choctaw village. When a number of skeletons had thus accumulated they were carried some distance away from the village, placed on the ground and covered over with a small mound of earth. In this custom we have an explanation of the many groups of small burial mounds which are found throughout the territory formerly occupied by the Choctaw. Most of these mounds are less than four feet high and average about thirty feet in diameter, and the bones which they contain are usually found in a compact mass near the center.

The most imposing earthworks of the southern states are not those which were erected for burial purposes, but the huge pyramid-shaped mounds, so characteristic of this area, on which were placed the temples and habitations of the chiefs. The largest of these structures in the south is the great Etowah mound in Georgia, which was probably built by the Cherokee. This famous earthwork is over sixty feet high and covers an area of no less than three acres. When we consider the manner in which this mound was erected, the laborious process of digging the earth with crude implements of flint or bone, gathering it up in small quantities in baskets or skins and slowly piling it up, load upon load, we realize

what a tremendous undertaking this must have been for a primitive people, and can not but marvel at the impelling force which drove them on to the completion of such a task. It is not in keeping with the indolent spirit which is so commonly attributed to the Indian. However, it should be borne in mind that, like other primitive peoples, the Indian was intensely religious, and willing to go to any length in order to see that his relations to the forces which controlled his universe should be observed with the dignity and rigidness that tradition demanded. The many large mounds on which their temples once stood and those erected as monuments over their dead thus afford direct evidence of the important place that religion held in the estimation of the Indian.

Slowly but steadily the mystery of the mounds is being solved—or rather, dispelled. Historical and archeological evidence now reveals with some certainty the identity of the builders of most of the mounds and other earthworks of the south. With but few exceptions they are the work of the Indian tribes which were found occupying the region in the sixteenth century. The most important of these tribes were the Timucua in Florida; the Cherokee in the Appalachian region of Georgia, Tennessee and the Carolinas; the Creeks in Georgia and Alabama; the Choctaw, Chickasaw and Natchez in Mississippi; and the Quapaw and Caddo in Arkansas and Louisiana. These tribes, together with smaller allied groups, possessed collectively perhaps the highest culture north of Mexico. Their country was rich in game, fish and wild food plants, and yet we find that these tribes practiced agriculture on a rather extensive scale. They were strictly sedentary, living in permanent villages, and their houses were well-built structures with frameworks of small logs

ANOTHER EXAMPLE OF WEEDEN ISLAND POTTERY.

A FLEXED SKELETON IN THE NACOOCHEE MOUND, NORTHEASTERN GEORGIA, SHOWING ORNAMENTS BURIED THEREWITH.

or poles and walls of wattle work and plastered clay. The more important towns were fortified by embankments of earth in which were set rows of stakes, while the mounds on which the temples and other principal buildings stood were no doubt used at times for purposes of defense.

The religion of most of the southern tribes was based upon sun worship, which was observed in its purest form among the Natchez. With this tribe sun worship was accompanied by a rigid caste system, under which the ruling class, or Suns, as they were called, were regarded as the direct descendants of the sky god, and exercised a most despotic power over their subjects. Among the other tribes of the south a much more democratic form of government prevailed. The chiefs had but little authority, and each village conducted its own affairs.

The mounds, as the most tangible of the Indian remains in the south, have been considered at some length. It is by no means certain, however, that the mound-building tribes were the first who occupied the region. Indeed, it might be more safely stated that they were the latest, for without doubt many of the mounds, large and small, were constructed after the coming of the whites, as is shown by the frequent finding of European objects in them, not only in the upper parts where they might be regarded as of secondary origin, but in the lower strata as well, and in some cases even beneath the mounds themselves. In addition, there is the evidence already referred to of the historic tribes using mounds as sites for certain of their buildings and erecting small mounds over the bones of their dead. Mound-building persisted, therefore, until a fairly late date.

When we seek to determine the origin of mound-building the facts all seem to point in one direction—to Mexico and Central America. In these regions there developed the highest civilizations in America, those of the Maya, Toltec and Aztec, whose intellectual and material achievements rivalled in splendor the ancient civilizations of the Old World. Here there are found great mounds of earth, similar in form and function to the large flat-topped mounds of the southern states. The mounds of the Maya, Toltec and Aztec were faced with stone, and the elaborate stone temples rising above them were of course vastly superior to the wooden structures which surmounted our own mounds. The underlying principle, however, was the same. There are other similarities that should be noted. Copper plates and ornaments of shell and stone found in the mounds bear decorations of a distinctly Mexican type. This resemblance is also observed in the stone pipes or idols and in the decorative designs on pottery.

Certain customs and various features of the religion and social organization of the southern tribes seem also to have been influenced by the higher cultures of Mexico and Central America. These facts are in no way startling or unexpected. On the contrary, it would be very strange if the influence of such high cultures as those of the Maya and Aztec should not have left some impression on surrounding peoples. While there seems to be but little doubt that such an influence was exerted, the process by which it was passed on is still obscure. It is possible that certain elements of Mexican or Central American culture were carried northward by means of a direct migration of tribes at an early date. On the other hand, the similarities in the culture of the two regions may merely indicate that the mound-building tribes of our southern states borrowed rather heavily from the more advanced tribes further south.

The problem of the origin and spread of any particular American culture leads sooner or later to the question of man's antiquity in America. On this point it can be stated that up to the present time there has appeared no clear evidence that would indicate the presence of man in either North or South America until after the last great ice invasion.

The American Indian is basically of Mongolian stock, and since emigrating from his Asiatic home has changed very little in physical type. The time of his arrival on this continent is highly problematical. While from a geological standpoint it was comparatively recent, it may well have been as much as ten thousand years ago. From that remote day until near the close of the fifteenth century A.D. the American Indian was removed from contact with the rest of the world. Thrown on his own resources, he developed his own social patterns, which, with his spread over the two continents, became more numerous and complex. America, in this respect, is an ideal laboratory in which to study the development of civilization and the rôle played by the diffusion of cultural elements from one people to another.

The region which we have been considering to-night occupies a strategic position, both geographically and culturally, in this larger scheme. Situated along the Gulf Coast, these southern tribes would be among the first to be affected by the more highly developed civilizations to the south. They were in a position to receive, absorb and pass on in diluted form the borrowed elements from these sources, and that, apparently, is what did happen. The archeology of this region, therefore, has more than a local significance. It forms, in fact, a most important link in the chain of accumulating evidence bearing on the problems of the origin and development of aboriginal culture in America.

SEXUAL REPRODUCTION IN WATER SILK

By Professor **FRANCIS E. LLOYD**

MCGILL UNIVERSITY

Throughout the realm of living things, the essential act of sexual reproduction takes place as a general rule when an exceedingly small male cell, the spermatozoid, unites with a relatively large one, the ovum or egg-cell. There are a number of forms, however, in which the sexual elements (gametes) are practically equal in size, and of these a fewer number in which the gametes may be seen with relative ease, and, because of equality of size, the behavior of each specifically studied.

There are two groups of plants of which this is true, the zygomycetes, of which the black moulds (Mucorineae) are well-known examples, and those green organisms, the conjugates, of which it may be especially said that they are equally yoked together. The plant which affords the subject of this account is a member of the latter group. It is so very well known, superficially at least to every one who has studied in a botanical laboratory, that to describe it seems almost superfluous. It is as necessary a type for the botanist as the frog is to the zoologist. Both are found growing and breeding in the same sort of places.

This plant, the "water-silk," "mermaids' tresses," known also by the less poetic and still less truly descriptive names "pond-scum" and "frog-spit," bears a scientific name both euphonious and graphic, *Spirogyra*, so much so that we may overlook any etymological faultiness. This plant more than any other, in the hands of the great plant physiologists Pfeffer and De Vries, led them to make the discoveries in osmosis which lie at the foundations of that now vast and intricate field of knowledge, physical chemistry. Its importance in relation to human knowledge therefore, no less than to the more circumscribed field of botany, entitles it to more than passing notice.

In the latter field it has had an important share in supplying material for important observations on sexuality from which our modern knowledge of this property has been derived. O. F. Mueller (1779), Vaucher (1805), De Bary (1858), Klebs, Pringsheim, Strasburger, Chmielewski and Hassal are among the numerous company of those who have cogitated on the meaning of the facts supplied by watching the behavior of this lowly organism. The appearance within the last very few years of lengthy and critical researches by Tröndle, Hemleben and Czurda shows that interest in it is still sustained. A full bibliography would include well toward one hundred names of students in Europe and America who have, in some way or other, studied *Spirogyra* critically, and most of them have thought on the problem of its sexual processes and properties.

What like, then, is this creature which has commanded the attention of the best thinkers in botanical science? And how is the process of sexual reproduction accomplished? Answers to these questions are presently attempted, always with the remembrance that there is more to know.

Spirogyra is a thread-like green water plant growing submersed or at times

floating at the surface, appearing in a mass as a uniform delicate green cloud. When lifted from the water it strings out like a lock of finest silky hair, whence one of its names. To the touch it feels smooth and mucilaginous, and it slips through the fingers with ease. If one places a mass of the plant in an aquarium, in a few hours it begins to grow upward, the filaments twining about each other, forming beautiful green curly locks reaching up to the light (fig. 1b, c). It may also grow about a support—is in fact a twining plant.

spora).[1] In figures 1a and 2 may be seen four different kinds, the smallest of which measures 26 microns (0.026 mm.), the largest 150 microns (0.15 mm.). The different figures are not at the same magnification, but it will be noted that with increase in size there is an increase in the coarseness of detail, indicating that the internal structures vary in respect of the size and character of the building stones, the architecture being the same.

Looking at the plant under the microscope it appears to be merely cylindrical, both ends, if seen, being alike. This,

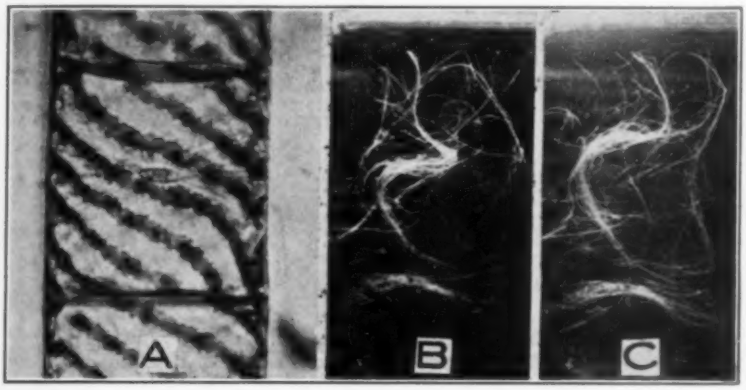


FIGURE 1.A. PART OF A FILAMENT OF *Spirogyra* TO SHOW THE SPIRAL PIGMENT BODY (CHLOROPLAST) AND THE NUCLEUS SUSPENDED BY THREADS OF PROTOPLASM. B. AND C. SUCCESSIVE PORTRAITS 2½ HOURS APART OF A CLUMP OF *Spirogyra* IN AN AQUARIUM, TO SHOW THE TWINING MOVEMENTS.

Examined under magnification, the separate threads, which are entirely without branching, are seen to be composed of a series of articles (cells) each like the other and having a definite structure. According to Transeau there are over one hundred species, differing in the minutiae of this structure, and in size; that is, in diameter, for they are all long and relatively most exceedingly slender. By measurement the diameter may be as little as one one hundredth of a millimeter (*Spirogyra tenuissima*) or twenty times that (*S. maxima mega-*

however, is only apparently true, since it really has an up-and-down structure or polarity. This is seen in young plants as they germinate from the spore. In such there is a basal end, which may become anchored to a convenient surface, and a top end which, by repeated growth and repeated cell-division, elongates into the filament. With much added length, it breaks away by accident or disease and the filament then is free. The upper end of a filament may

[1] Data transmitted by the courtesy of Professor Transeau.

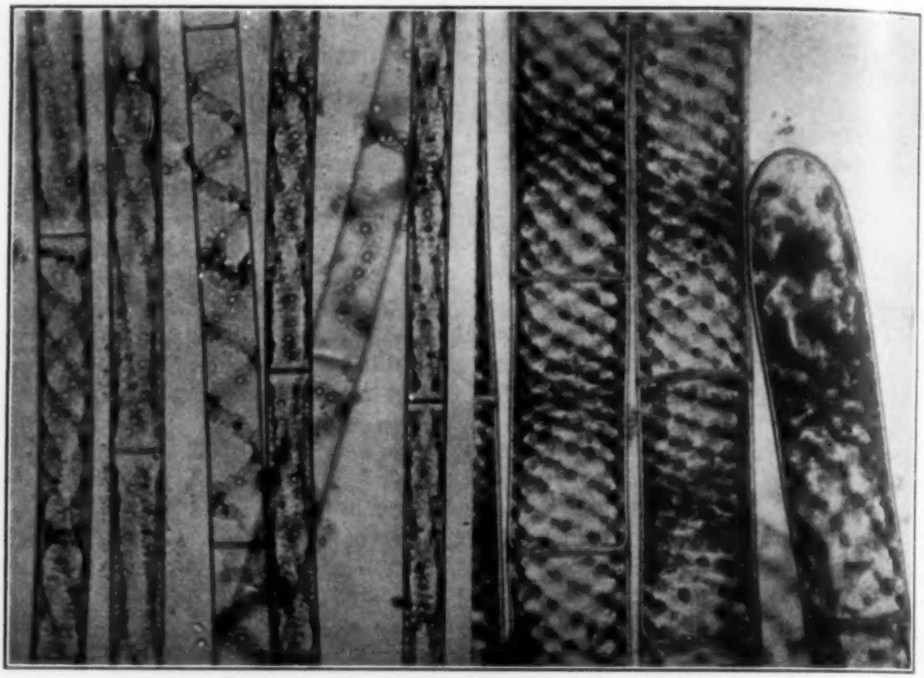


FIGURE 2. FOUR DIFFERENT SPECIES OF SPIROGYRA.

sometimes be found (fig. 2), though we may not always be quite sure that we are not looking at an end secondarily formed after a break in the thread has occurred. The filaments have the ability on occasion of sending out rootlike processes (haptera) by which they anchor and this seems to occur most frequently when short pieces of the plant lie at the bottom of their watery habitat or of an aquarium (figure 3e). When the favorable time of spring has come, these fragments together with the sporelings grow apace and the resulting myriads of individuals compose the green cloudy masses seen in quiet ponds.

In order to approach the matter to which we have addressed ourselves, we must now examine more closely the cell. Except in superficial details, all the cells are alike. On examining figure 2 a conspicuous feature is noticeable, namely, that each cell is traversed by one or more left-handed spiral bands which may be steeply inclined to the axis or less so, this varying even in the same individual. These (the chloroplasts) in life are a clear, grass green, and contain the characteristic green pigment chlorophyll, a fluorescent substance, and, when the cell is suitably illuminated, cause the chloroplasts to appear deep red. Thus seen, the rest of the cell is invisible and one sees only the brightly shining red spirals. The band is folded longitudinally, so that in transverse section it appears as a shallow V. It can be seen by the figures also that the steepness of the spirals varies with the species and is greater in the middle of the cell than elsewhere. This will be explained shortly.

Choosing a species of *Spirogyra* in which only one chloroplast occurs, for

the sake of simplicity, we examine a single cell to acquaint ourselves with its structure, and for assistance turn to the accompanying diagram (figure 4). We distinguish first, on the outside, a firm, tubular shell, a membrane of cellulose which is continuous from one cell to another. Within this is a series of other cellulose shells each proper to a single cell and forming a closed cylinder. The inner surface of this wall is clothed by a layer of the living material—this probably penetrates also throughout the cell-wall—which I estimate to be about one micron thick or less in the small species shown in figure 3. It is so transparent and apparently structureless that its outline, when in normal position, evades the vision (figure 5a). In it minute granules in varying numbers may be seen, moving more or less steadily in one direction or another. These, like leaves floating on a quiet stream, indicate the direction of flow of currents in the protoplasm. The visual demonstration of this delicate layer of protoplasm may be easily made by causing it to recede from the cell wall by bathing the cell with a 10 per cent. sugar solution. The protoplasmic sac may then be seen lying free in the cavity of the cell wall (figure 5b).

The whole relatively vast interior of the cell is occupied by the sap: water with sugars, salts, tannin and doubtless other substances in solution, in quantity approximately equal *in toto* to the amount of about 10 per cent. if it were all sugar and with colloidal material in suspension, appearing milky with the dark-field illuminator. Lying in this thin layer of protoplasm which bulges out to accommodate it is the chloroplast.

FIGURE 3. A–D. EARLY STAGES IN THE DEVELOPMENT OF A SPIROGYRA PLANT FROM THE SPORE. A. TWO SPORES IN DIFFERENT POSITIONS; THAT ON THE RIGHT HAS RUPTURED THE SPORE CASE, THE SPLIT TO BE SEEN AT THE UPPER PART OF THE LIMB. B. YOUNG ONE-CELLED STAGE. C. LATE ONE-CELLED STAGE AND D. TWO-CELLED STAGE. E. FRAGMENT OF A FILAMENT WHICH HAS ATTACHED ITSELF BY A ROOTLET.

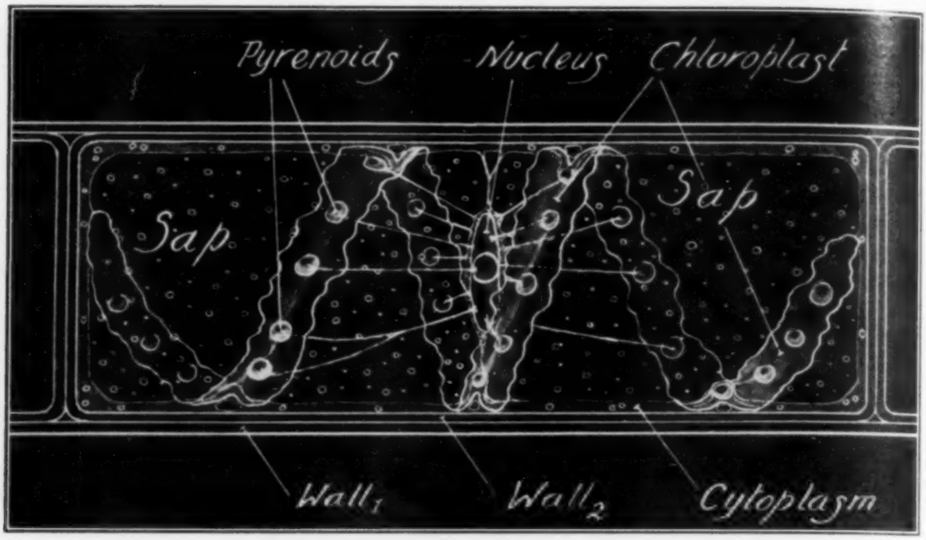


FIGURE 4. DIAGRAM OF A CELL OF *Spirogyra* DESIGNED TO INDICATE THE IMPORTANT FEATURES OF STRUCTURE. COMPARE WITH FIGURES 1 AND 5.

From this spiral bulging ridge—and sometimes from other points—delicate threads of protoplasm slightly displacing the chloroplasts extend radially toward a lenticular body, the nucleus, occupying the center of the cell. Surrounding the nucleus is a thin layer of protoplasm, so that the chloroplast and nucleus lie in and are fully covered by it.

It will be seen that the great bulk of the cell is water. This is held in place by the osmotic attraction of the substances in solution in the sap from which they can not escape because they can not pass through the thin layer of protoplasm lining the cellulose wall, so long as the cell is living. So much for the structure of the cell.

When sexual reproduction takes place two neighboring cells in a filament or two cells in neighboring filaments unite to form a single cell, the zygote, the total volume of which is 25 to 30 per cent. of the total of the two original cells. It normally contains the whole of both gametes, less only the water of the sap and possibly some solutes. Clothed with a triplex covering (figure 9h) it passes a lengthy period in a resting condition; it is this which produces in spring the sporeling (figure 3a–d). We now examine in detail the behavior of the gametes in preparing for sexual union, here called conjugation.

First when two neighboring cells conjugate. The first evidence consists in the gradual outgrowth of the side wall on each side of the transverse partition separating the gametes (figure 6). At length (24 hours or so) there has formed a curved tube from one cell of the gamete to the other, but they are still separated by a diaphragm, of cellulose of course. Before the living material of the gametes can come into contact, this diaphragm must disappear. This is brought about by digestion, speaking physiologically, by hydrolysis, as the chemist would say. The progress of the change which leads to dissolution may

be watched. First the membrane swells and becomes lax, so that it hangs like a translucent drapery between the gametes (figure 6d). Varying pressure of one gamete on the other causes the diaphragm to bulge now one way and now the other till it is finally perforated, and the gametes come into contact, when, if conditions are favorable, they fuse (figure 7a). Of these conditions, that of surface tension appears very important, just as, in an emulsion of oil in water, the oil drops will run together if water alone is used, but will not do so if something of the nature of a soap is introduced, a soap solution having a lower surface tension than water. That this condition is a real one in the case we are considering, it need only be pointed out that the gametes may be crowded into close intimacy without fusing, each forming a parthenospore, that is, a spore without sexual union (figure 6e).

The region of initial fusion is small (figure 7a) but rapidly the softened wall is broken down by the pressure of the stream of protoplasm as it flows over to join the female. Since the female occupies the whole of the cavity formed by the cell-wall, and since the male occupies the whole of his at first, the question may well be asked what happens to two bodies to enable them to condense and in consequence to occupy only one third to one fourth of their original volume. This question is seventy-five years old at least, De Bary being the first to have pondered the matter. He thought that the gametes contract by the excretion of water, or an extremely dilute watery solution. So far he was right, but he had nothing to say about how this is accomplished beyond saying that the contraction of the protoplasm is like that which occurs when the cells are bathed with a solution of sugar of higher concentration than that of the sap, and this did not help much. Later it was thought there was secreted by the protoplasm a sort of mucilage or jelly-like substance which had the effect of crowding it into less space; but the author of this conception,

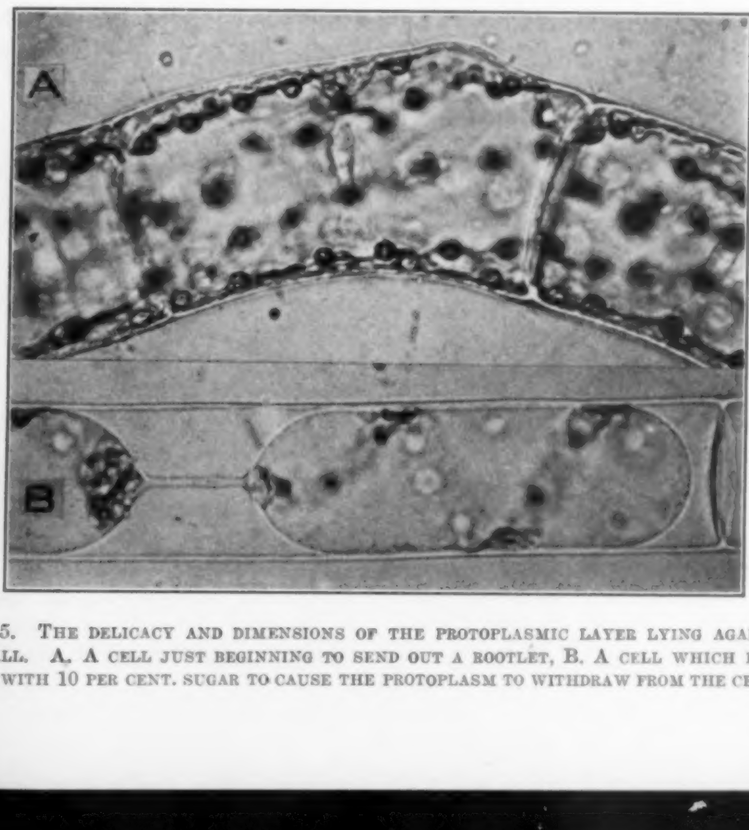


FIGURE 5. THE DELICACY AND DIMENSIONS OF THE PROTOPLASMIC LAYER LYING AGAINST THE CELL WALL. A, A CELL JUST BEGINNING TO SEND OUT A ROOTLET, B, A CELL WHICH HAS BEEN TREATED WITH 10 PER CENT. SUGAR TO CAUSE THE PROTOPLASM TO WITHDRAW FROM THE CELL WALL.

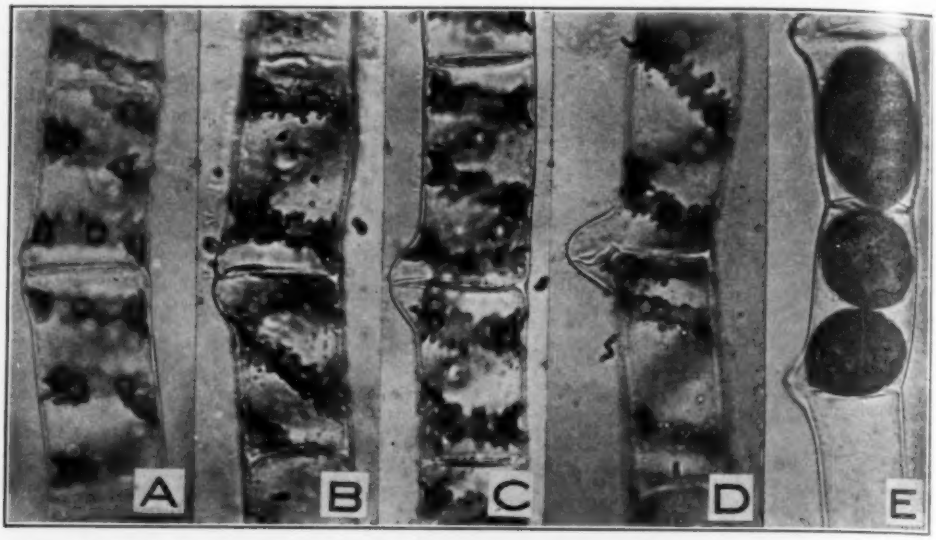


FIGURE 6. A–D. SUCCESSIVE STAGES IN THE GROWTH OF THE TUBE TO PERMIT THE TRANSFER OF THE MALE TO THE FEMALE SEX-CELL. FEMALE CELL BELOW IN A, ABOVE IN B, C AND D. IN D THE CELLULOSE PARTITION IS SWOLLEN AND BREAKING DOWN. E. A NORMAL SPORE COMPOSED OF FUSED GAMETES (ABOVE) AND TWO PARTHENOSPORES DUE TO FAILURE OF THE GAMETES TO FUSE THOUGH IN CONTACT.

C. E. Overton (1888), took no steps to prove the truth of it, which would have been difficult since it has turned out to be false. The essence of the idea as it then prevailed was that the process is a mechanically produced one, and that the gametes are passive. Against this unphysiological view Klebs took issue (1897) and thought to have found evidence that the male gamete condenses in response to a stimulus derived from the female. Whether this be true or not, and we can not yet say, Klebs did a good thing in insisting that, in his opinion, the whole process is a complicated physiological one, and this we now know to be the case. Klebs, in the course of his researches, made an important observation, namely, that just previous to conjugation the concentration of the sap of the gametes is reduced to nearly one half the usual value. This observation has recently been confirmed by Czurda and by myself, but Klebs was not led further into the problem and left it much as he found it. So far as I am aware no effort was made to explain the mechanics of condensation till Chodat (1910) advanced the theory that the gametes lose their power to retain the substances held in solution in the cell-sap, and in consequence lose also the power to retain the water in which these substances are dissolved. Chodat, however, did not determine if this were indeed the case, and I have recently shown that it is not, but quite the reverse. If this be true, the gametes must retain their avidity for water, which they do in the measure of the concentration of solution of their saps. In spite of this they can and do excrete water during condensation. The only remaining attempt to solve the problem is a recent one made by V. Czurda (1925), who took his point of departure from the observation of Klebs, above mentioned, arguing that the reduction of concentration of the sap becomes great enough to permit surface tension to come into play, separating the

protoplasm from the cell-wall and squeezing the contents of the male through the opening in the diaphragm, just as a soap bubble will contract when we cease blowing it up and allow the air to flow out—an exactly similar result due to the same conditions. At the time when the condensation takes place, however, the concentration of solution of the sap, while lower in the male than in the female, remains of value high enough so that water is taken up by it even during conjugation, as I have proved experimentally. Evidently there is something lacking even in Czurda's explanation, and this appears more certain when we know that the flow of male protoplasm into the female is not a steady movement but an oscillatory one, that is, the movement is frequently reversed. The normal total effect is a net result of condensations and enlargements of both gametes—the algebraic sum of plus and minus effects. How is this to be accounted for? The answer is, I venture to think, as follows.

During the period preceding fusion, not only does the concentration of cell sap go down—as Klebs found, to about 50 per cent. of the original value—but the male becomes attached to the partition wall separating the two gametes. This attachment serves as a point of leverage. Other changes occur which need not be considered here. When the time of fusion approaches—whether just before or at the time is not yet certain—the male contracts transversely at the end removed further from the female (figure 7b). It seems fairly certain that this contraction is not a passive matter, but active; that it is the same sort of contraction seen in other protoplasms. This phase of behavior lasts but a short time, or, if it continues, it is unobservable. So far as we can see, the only result of this contraction is the slight separation of the male protoplasm from the cell wall at the closed end and along the outer wall, but more at the distal than at the proximal end. One bit of evidence that this is true contraction is seen in the fact that the protoplasm leaves the closed end wall as if it were a cast, instead of immediately rounding off, as in figure 5b, as it should if the movement were passive. At the same time we know that the protoplasm has a

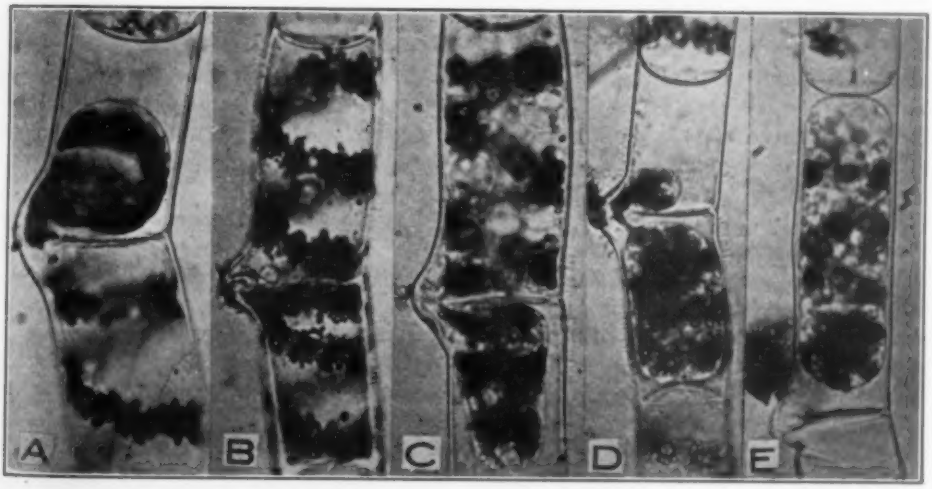


FIGURE 7. SERIES OF STAGES IN THE UNION OF THE GAMETES. A. THE FIRST AREA OF CONTACT AND FUSION IS SEEN. B. THE FIRST CONTRACTION OF THE MALE (BELOW). C, D AND E. SUCCESSIVE STAGES IN WHICH THE WATER EXCRETORY BLISTERS (CONTRACTILE VACUOLES) CAN BE SEEN.

higher viscosity here, that it yields to surface tension therefore only slowly. But if we apply a strong enough solution of sugar—it need be only slightly in excess of the concentration of the sap—the end rounds off more rapidly. Further, if we do this before fusion has occurred, the whole male protoplasm acts much as it does during contraction. While these evidences are not wholly convincing, the impression of active contraction is difficult to set aside.

As the contraction proceeds, a most remarkable phenomenon becomes apparent. At first a few minute bubbles appear in the very thin layer of protoplasm inclosing the sap (figure 7c), at first so small and few that they may quite escape notice, and earlier in the male than in the female, but normally always in both. These bubbles become gradually more numerous and larger, the earlier formed disappearing, the newer taking their places, till the whole of both gametes has the appearance of a froth (figure 7c). These bubbles are filled with water containing but little else. Their origin and growth is due to water taken by diffusion from the sap cavity; their disappearance to their bursting outwardly, emptying their contained water into the space between the protoplasm and the cell-wall (figure 8). The whole activity can be stopped at any time by a suitably concentrated solution of sugar. As a result of the constant formation of bubbles and their outward bursting, the amount of water in the sap cavity is constantly reduced, surface tension comes into play, and the contents of the male are forced through the opening into the female (figure 7 c-d). The process, which occupies one half to two hours, is most interesting and dramatic to watch. As soon as a few bubbles in the male have burst, the volume is seen to be smaller. Nothing further could happen, however, did not the female lose some of her volume in like manner. This permits a forward movement of male

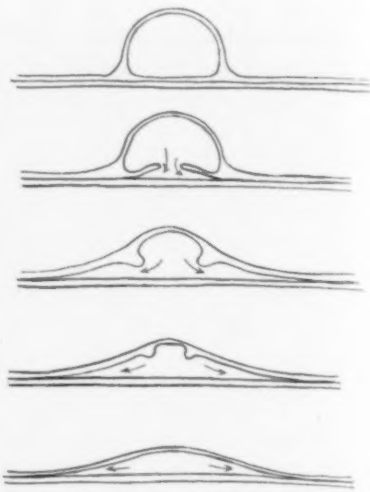


FIGURE 8. DIAGRAMS WHICH SHOW THE METHOD BY WHICH WATER IS EXCRETED FROM THE INSIDE OF THE GAMETES AND THROWN OUT BY THE BURSTING OF EXCRETORY BLISTERS (CONTRACTILE VACUOLES).

protoplasm. If the process of water excretion in the female slacks up at all, water will again be taken up and partially displace the male protoplasm, which then flows back. Normally the excretion of water is rapid enough so that the total forward movement of the male is in excess of the retreat. Soon the sap cavity of the male becomes so far reduced that it can pass in its entirety through the opening, the female in the meantime having suffered like reduction in volume. One may foretell such forward movements by noting the bursting of the excretory bubbles in the female. The reduction of volume and with it of surface of the male permits the more and more effective play of surface tension, and at length it completes its passage, the last portion often being composed of a protoplasmic spume. I have said nothing about the behavior of the chloroplast in the above description. This being green and quite easily visible, registers to the vision the movements which occur. Often a piece of it is pushed through the opening only to be withdrawn. When a considerable por-

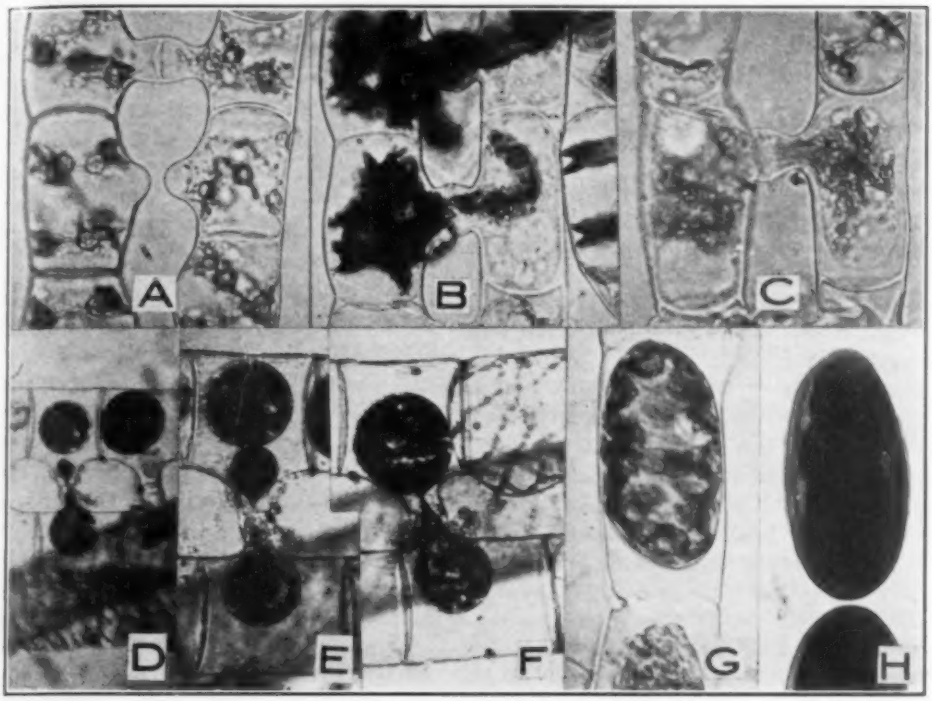


FIGURE 9. TRANSVERSE CONJUGATION. A–C. *Spirogyra varians.* THE CONTRACTILE VACUOLES MAY BE SEEN IN THE MALE (ON THE RIGHT). D–F. *Spirogyra maxima.* HERE THE REMARKABLE EARLY CONDENSATION OF THE GAMETES IS TO BE SEEN, AND THE POSITION OF THE MALE ATTACHED TO THE ENTRANCE OF THE CONJUGATION TUBE. A, BEFORE, B AT THE MOMENT OF, AND C, AFTER FUSION. G. SPORE SHOWING THE TWO SEX-NUCLEI JUST BEFORE FUSION. H. RESTING SPORE WITH THICK WALL.

tion has passed over, a reversal of flow may result in breaking it, or at all events in stretching it almost to the breaking point (figure 7d). The movements—stretching, folding and twining—of this plastic ribbon of green lend a strong dramatic element to the process.

The reader may now ask why the female does not flow toward the male or why a deadlock does not occur. Usually the male is smaller than the female, but not always, and then with no necessary interference with the usual procedure. In any event, the male condenses earlier and more rapidly and is anchored at the forward end, while the female remains turgid enough to stay anchored by mere volume, assisted by a previous bulging of the cell wall (figure 7).

After the male has passed entirely over, the combined protoplasms (the zygote, figure 7e) is still larger than it is in its final condition (figure 9g). The further condensation proceeds quite as before, until all the free sap has been discharged. The definitive form is fixed by the secretion of membranes (figure 9h) which remain entire till the time of germination.

What then are these bubbles? I have called them so because that is what they really are, only they go by another name in books, that of contractile vacuoles. They have long been known to occur in

the lower forms of animal life—in *Amoeba, Paramecium*, the *Heliozoa* and the like, and I have recently found them in the curious animalcule *Vampyrella* which feeds on *Spirogyra* alone, each animal having them in large numbers. They occur also in the motile forms of some of the lower plants, but they have never previously been observed in *Spirogyra*. But we are made aware of the fact that in the gametes of this genus—and we shall probably find them elsewhere—they are far more conspicuous both in numbers and size than in any other known forms.

In the preceding account the reader has been asked to consider only the kind of conjugation which proceeds between neighboring cells. It remains to indicate briefly the general character of the process when conjugation takes place between cells in neighboring filaments. Figure 9a shows the process at its inception. In some forms of *Spirogyra*, the whole procedure after fusion is in all essential respects like that above detailed (figures 9b–c). In others, however, the male gamete may condense a great deal before entering the transverse canal seen in figures 9d–f, and indeed the same condition may occur in the female as well. This condition is the one which dominated the thought of De Bary. It has been overlooked, however, that the male as seen in the figures remains attached to the neck of the conjugation tube, thus supplying the necessary leverage so that the pressure exerted at the decreasing surface of the male may urge the protoplasm through the opening. Fusion of the male and female is accomplished only if, by crowding (figure 9e), the surfaces come into contact and again if the surface tension conditions are favorable.

Although the purpose of this paper has been achieved, there remain, among many further details, two points which will naturally occur to the reader, namely, the fate to the chloroplasts and of the nuclei. If nothing happened, there would be an accumulation of both these organs resulting from the union of gametes.

Like the gametes themselves, their nuclei also fuse slowly to form one. This fact we know, but the details we are ignorant of. Figure 9g shows the two nuclei in contact but before actual fusion.

The chloroplasts, however, behave in one of two ways. Those of the male gamete degenerate in the zygote (Chmielewski, Troendle) or they unite with those in the female by fusion (Overton), at least these two views are held at present. At all events the number of chloroplasts remains constant.

ORGANIZATION AND VARIATION IN PROTOZOA

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A FAVORITE analogy of the late Dr. Loeb was to liken the cell to a chemical machine in which, through oxidation and other chemical processes of metabolism the chemical energy of organic compounds is utilized and represented by a multitude of activities which we regard as vital manifestations. The same idea is expressed by Professor Wilson, who writes in "The Cell": "We assume, as our fundamental working hypothesis, that the specificity of each kind of cell depends essentially upon what we call its organization, *i.e.*, upon the construction of the cell machine, in some sense or other—morphological, physical or chemical" (p. 635). Let us take as our point of departure the conception of a protozoon as a machine-like organism, with a visible organization expressed by definite and characteristic cell structures, and with activities which represent the same fundamental vital functions that every living thing performs. The adult structures which we actually see are the final product of the possibilities of any particular organization. They differ in different genera and in different species of the same genus, but are apparently identical in all examples of the same species. These are the characters which afford a basis for the so-called natural classification of the Protozoa, and they are the most evident of the structural peculiarities of any given type.

Other structural evidences of organization are not usually visible in an organism in its living state but are more or less prominent in properly made preparations. Here the nuclei and kinetic elements are visible evidence of organization which have been the subjects of study by a great number of observers who are interested primarily in cytology of the Protozoa. Basal bodies of flagella and cilia, blepharoplasts, centrosomes, centrioles, coordinating fibrils and neuromotor systems of all kinds, together with plastids and metaplastids, furnish additional evidence of the particular organization of the cell.

Apart from these more or less easily visible evidences of organization, which may be termed the *derived organization*, is the fundamental, invisible and entirely unknown organization of the protoplasm of the cell. The visible evidences may disappear at times or may be temporarily altered, but from the invisible *fundamental organization* they are again reformed or restored to their characteristic and specific types.

This fundamental organization which gives rise to the specific, visible structures in each type of Protozoa may be conceived as due to the particular kind and arrangement of the colloidal substances—proteins, carbohydrates, fats, mineral elements in the form of salts and water—which make up protoplasm. The particular composition (*e.g.*, specificity of the proteins) and arrangement of such substances are presumably different in different species and are probably more or less different in individuals

of the same species; and there is abundant evidence to show that they vary at different times in the same individual. In the last analysis what I mean by the term organization is this unknown but specific combination of protoplasmic substances.

It is in this ultimate organization that the potentialities, both structural and functional, of a species are contained, and so long as the complete organization is represented, any small bit of the protoplasm is capable of forming the whole. Here are two organisms, A, a *Stentor polymorphus,* B, a *Uroleptus mobilis;* their visible organizations are entirely different. If we cut a small piece from the *Stentor,* this piece rounds out into a homogeneous ball. If we cut a similar piece from *Uroleptus,* this piece likewise rounds out in an apparently homogeneous ball. If the two balls are of similar size there is no visible difference between them. Yet they are quite as different as the adult *Stentor* is different from the adult *Uroleptus,* and in the proper medium the one develops into a perfect *Stentor,* the other into a perfect *Uroleptus.* The characteristic specific organization is present in each such fragment, and the developed organism is the expression in a structural and functional sense of these organizations. The problem to the student of variation is: Can this fundamental organization be permanently changed so that it will give rise to adults with visible structures and activities of different types from the normal species?

These organizations, visible and invisible, are the chemical machines which do the work of living. In an appropriate medium in which oxygen, free or combined, is of the first importance, the various substances of protoplasm begin a series of coordinated and correlated chemical and physical activities manifested by movement, by feeding and the sequential processes of nutrition, by excretion of waste, by growth and ultimately by reproduction. The organization is active in all its parts.

Living things are not thus active at all times, even in the presence of oxygen and abundant food. There may be long periods in which the machine is static and the constituent parts inactive in the usual metabolic sense. In our descriptions we are accustomed to pass over such phases rather hastily or to ignore them altogether. But they are worthy of careful consideration. I refer to the various phases of encystment of flagellates and ciliates, to sporocysts and spores of Sarcodina and Sporozoa. It gives me no satisfaction to pass these by as arrested stages in metabolism, or as stages in which protoplasmic activities are in abeyance or reduced to a mere trace of the usual metabolic activities. The protoplasm is here enclosed in an impenetrable wall of chitin, and when dried oxygen and water are inaccessible. An encysted ciliated protozoön is a homogeneous ball of protoplasm enclosed in such a cyst membrane. There is absolutely no structural evidence of the species to which the ball belongs unless the cyst wall has some peculiarity of structure by which it can be recognized. In this condition the ball may remain unchanged for months or years in a dried state. Without distorting beyond recognition the usual conception of metabolism there is no evidence of vital activity in such encysted forms. There is probably molecular activity as in all substances, but no metabolism as usually understood. There are no waste products, there is no evidence of irritability, and no change in that ball of protoplasm, at least no change that can be recognized. The same is true of a spore or a seed that remains in the dried condition for months or years; and the same is true of a dried rotifer. For several years I had a bottle of dried dust in the form of amorphous particles on my shelf

at Columbia. From time to time I would take out a pinch of this dust and drop the particles into a culture dish of water. In a very short time the water would be teeming with fully formed rotifers in full activity, as many of them as there were particles introduced.

This phenomenon can mean only one thing, *viz.*, that the dried particles were living rotifers; that life was there all the time and that the organization was unimpaired. Similarly with our seeds, spores or encysted ciliate; they are alive all the time; their organizations are perfect, but in this state the constituent parts of their protoplasm are inactive. Here then it is the organization that persists; it is the organization that is continuous and has been continuous through historic and prehistoric ages, and barring accidents has the potential of an indefinitely continued existence in the future. There seems to be no alternative for the conclusion that what we call life, in the sense of perpetuity at least, is the same thing as that which we call organization in its modern and physical interpretation.

We are accustomed to speak of life as dynamic; as force; as protoplasm in action; and in the next breath to speak of life as continuous from protoplasmic beginnings down to the present time. At such times are we not speaking loosely? Do we mean exactly what we say? I think not. Is the automobile going forty miles an hour the same thing as it is when standing in the garage? Its organization indeed is the same, but in the garage the constituent parts, while all in their proper places, are quiet and inactive. Introduce oxygen, give it gasoline and add a spark; oxidation occurs and through the transformation of energy the parts of the engine move; turn a lever, connect the engine with the transmission and the whole mechanism moves, and the more food we give the engine the faster goes the aggregate. Here the many parts are so put together that they interact harmoniously; they are properly correlated and coordinated and a smoothly running car is the result. The many different car organizations on the road are all performing the same fundamental functions, but their organizations are different. Now the activity of the car is not permanent; its movements are not permanent; that which is permanent is its organization.

This crude analogy will illustrate what I should like to present as a distinction between life and vitality. Life, as we have seen, is inseparably bound up with organization; and what we ordinarily mean by continuity of life is continuity of organization. Vitality I would define as the sum-total of the activities performed by the organization. Vitality is the dynamic phase of life; it can be studied and measured; but it is not continuous, at least not in the group of organisms of which I am speaking. Life, on the other hand, can not be measured; as organizations we know little about it; but life is continuous. The dried rotifer, the cyst or the spore has life and has the possibility of vitality so long as its organization is retained. Let the organization disintegrate by surface oxidation, by continued molecular activity, or through other agencies and the seed will not develop, the spore and the cyst will not germinate, the dried rotifer will never again spread its fascinating wheels.

Here, however, the analogy ends and we are forced to abandon the conception of a machine in relation to the functioning organism. When vitality begins; when the constituent parts are in the full activity of metabolism, the organization is no longer fixed, but each substance in it is subject to changes brought about by its own activities. The encysted protozoon in its dried state is undifferentiated; it consists of substances in the arrangement of the fundamental organi-

zation. Under proper conditions water and oxygen are absorbed through the cyst membrane and the ball of protoplasm begins to differentiate. Changes are first observed on the periphery and, presumably as a result of oxidation, the characteristic motile organs, absent until now, are differentiated from the cortex. Cortical apertures, mouth and anus are formed, and the normal shape of the body is assumed, all within the still unbroken but now permeable cyst wall. The active organism, with its motile organs in full swing, breaks through its walls and begins its vegetative life as a highly labile, animated bit of protoplasm with all the initial visible differentiations of its type.

This phenomenon of differentiation from the apparently homogeneous ball of protoplasm may well be included in the category of ontogenetic or developmental processes. It is the evolution or consecutive unfolding of the potentialities of the organization and is characteristic of all encysted Protozoa. Under other conditions, and when encystment is not involved, differentiation is not so rapid but resembles processes of regeneration, as with the cut fragments of *Stentor* or *Uroleptus*. So it is with young organisms formed by budding or by multiple division; in these small bits of fundamental organization processes of differentiation are relatively slow and are apparently dependent upon metabolism and growth. Thus the bud of an *Acanthocystis*, according to Schaudinn, requires from five to six days of growth before the full expression of the *Acanthocystis* derived organization is attained. Or a polycystid gregarine requires days of feeding and growth before it changes from the undifferentiated sporozoite to the differentiated adult form. A multitude of similar examples might be selected from the enormous list of known Protozoa, but these two cases will illustrate what I mean by the statement that the organization becomes differentiated as a result of its own activities. Not only is this difference expressed by structures in the adult which were not present in the young form, but it is highly probable that changes in the fundamental organization or invisible differentiations have gone on as well. I have previously used the phrase interdivisional differentiation to characterize this phenomenon and have illustrated it with the merotomy experiments on *Uronychia* by Dr. Young and by myself. Two individuals of *Uronychia transfuga*, one five hours old, the other twenty hours old, appear to be identical, but if we transect each the fragments do not behave in the same way in respect to regeneration. The emicronucleate fragment from the young individual will not regenerate at all; but the emicronucleate piece from the older individual regenerates a perfect individual but without a micronucleus. Something in the organization has changed during the twenty-hour interval of metabolic activity, some differentiation of the organization has occurred whereby the older enucleated fragment is able to restore a completely differentiated individual by regeneration.

Furthermore, this change or differentiation, whatever it is, is lost with the processes of division, which, in my experiments, occurred once in approximately twenty-six hours. The young cell has now lost the power to regenerate in the absence of the micronucleus and does not regain this power until late in interdivisional life. It looks very much as though the differentiated organization were thoroughly cleansed of the accumulated products of differentiation by the processes at division, or, to use Child's expression, had been dedifferentiated and restored to the labile condition characteristic of the young organism.

There is abundant evidence of such differentiation and dedifferentiation in

the different classes of the Protozoa. In many cases metaplastids are formed as a result of metabolic activities and these, in the gruelling processes of cell division, are thrown off or absorbed. Not only metaplastids but functional structures are often similarly discarded or absorbed. Amongst the flagellates we have numerous examples of the discarding of flagella and other kinetic elements at division. For example, in *Lophomonas blattarum* the great brush of flagella with their basal bodies, blepharoplasts and axial strand are all discarded and the full complex is reformed for each of the daughter cells. It may be significant that this regeneration occurs in a protoplasmic region far removed from the site of the old complex. In ciliates, easily observed in the more complex forms like the Euplotidae, there is a similar absorption of the whole complicated motile apparatus and a regeneration of a double set of undulating membranes, membranelles and cirri which are thus at all times commensurate in size with the size of the young cells. In multiple division, also, accumulated products of activity are left out entirely from the protoplasm of the young organisms, as in the familiar case of different species of *Plasmodium* and other hemosporidia where the melanin granules are discarded with a residuum of protoplasm at the time of division.

If the visible differentiations are thus discarded at division, to be formed anew, it requires no hypertrophied credulity to believe that analogous processes of housecleaning at division periods are taking place in the general organization and that, as a result, the products of cell division are not only youthful organisms but possess an organization which is essentially different from that of the old parent cell from which they came, and a lability which is characteristic of an organism fresh from a cyst. In short, division of the cell involves processes which bring about a more or less complete reorganization of the protoplasmic substances. The cell is apparently restored to the condition of its fundamental organization from which two young organisms immediately develop their visible evidences of organization anew.

Here, as I believe, is the possibility of the explanation of some of the results of isolation cultures in which no definite life cycle has been observed. The long-continued culture of *Actinophrys sol* by Bêlar, the even longer culture of *Eudorina elegans* by Hartmann, the incomplete culture of *Glaucoma scintillans* by Enriques, the upwards of 2,000 generations of transplants of fibroblasts in tissue cultures by Carrel and Ebeling, all may have their explanation in the periodic reorganization which occurs at cell division and the restoration of vitality which accompanies that reorganization. Here, too, is a possible explanation of the continued existence of animal flagellates and many of the plant flagellates which so far as we know never undergo processes of fertilization. It is possible also that conditions of the milieu may be so prepared that the organism is helped or injured at these critical periods and that it will live longer or shorter under such isolation cultures without endomixis or conjugation than it will live under the usual environmental conditions.

In the majority of ciliates in culture, in Sporozoa and in Foraminifera, continued successive divisions bring unmistakable evidence of waning vitality, and, without endomixis or fertilization, ultimate death. I have outlined my views on the rejuvenating effects of conjugation so often that I will not review the evidence here. I will merely point out again that with fertilization by conjugation there is an even more drastic overhauling of the old organization, a discarding and absorption of the old cell

organs, including the macronucleus, that have survived many a division, and a reorganization that restores the cell to the young, labile condition characteristic of young forms fresh from their cysts. Whether this waning vitality and ultimate death is due to the accumulation of products of metabolism as suggested by Minot, and later by Child, or whether it is due to a progressive modification of the organization itself is not known. There is some evidence, which I will briefly outline, that it is due to the latter.

In old age protoplasm in isolation cultures not only is there a great retardation of metabolic processes as shown by the rate of division, but the division processes themselves are pathological in a large percentage of cases, and monsters of fantastic shape and frequently of huge size are formed. This indeed might be explained as due to the accumulation of waste matters which hinder normal processes. But similar old individuals will conjugate and such conjugations are followed by the usual accompanying phenomena of reorganization. The offspring thus produced, however, in the majority of cases, are short-lived and have a weakened vitality throughout. It may be significant, however, that occasionally the progeny from such old age individuals have a remarkably high vitality. Thus in *Uroleptus mobilis* one ex-conjugant from parents in the 225th generation—parents which had only thirty-two more generations before they died from exhaustion—lived for 643 days and divided 597 times. This case, Series 19 in my experiments, was a remarkable exception to the majority of my 128 other series of *Uroleptus,* few of which live more than 250 days and few divide more than 300 times. It is a still more remarkable exception to other cases of ex-conjugants from old age parents where the length of life is rarely more than fifty days. In such cases the old organization is so changed that reorganization is impossible or incomplete. It is theoretically possible to explain the unusual case as due to the fortunate combination of highly modified organizations brought about by long-continued metabolism and division. In no case, however, have such exceptional series given rise to offspring with a similar exceptional vitality.

Other evidence of a changed organization with age is shown by Sporozoa, particularly by the gregarines and the Neosporidia, and by the Mycetozoa amongst the rhizopods. Here, new structures appear in the organization which are formed only in the very last stages of life of the individual. In this connection I will enumerate only the sporoducts, cyst walls and polar capsules of the Sporozoa, or the capillitia, elaters and similar final structures of the Mycetozoa.

Further evidence of progressive change of the organization with continued metabolism is furnished by the multiple phenomena of gamete formation. No protozoön is mature immediately after fertilization. With Sporozoa and Foraminifera and many flagellates gamete formation is the final expression of a modified organization. In Infusoria gametes are rarely formed, but individuals appear after variable periods in different ciliates which are mature and ready for conjugation. The onset of the change in organization which makes gamete formation or conjugation possible is sudden and is advertised by no peculiarities of structure or function. Yesterday thousands of *Uroleptus mobilis* in a container showed not one pair of conjugating individuals; to-day fully 90 per cent. in that container are conjugating. The environmental conditions have something to do with the change, but unless the protoplasm is in the appropriate condition of organiza-

tion, such environmental factors will be ineffective.

With gamete-forming types this change which we call maturity is fatal; the gametes apparently have lost their metabolic powers and without fertilization they die. Their differentiations are antithetic and apparently complementary, for with their union, vitality is completely restored and a young labile organism results. With ciliates the change in organization is not so sudden but appears to be progressive and failure to conjugate at any given time is not immediately fatal. This is easily demonstrated by separating two individuals which have just begun to conjugate. With *Uroleptus*, however, such separation does not prevent the reorganization that accompanies complete conjugation and a new, young, labile organism results.

This latter phenomenon is of the same nature as the asexual reorganization in *Paramecium* discovered by Woodruff and Erdmann in 1914. Its discovery marks the culmination of the brilliant work of Woodruff on *Paramecium aurelia* which he began in 1907. It is a periodic process of reorganization, parallelling the reorganization processes of conjugation and involves deep-seated changes in the organization which result in a youthful and labile individual. In *Paramecium*, except for depression, there is no external evidence of the processes going on within. In other ciliates this process, called endomixis by Woodruff and Erdmann, precedes and accompanies the first stages of encystment, so that endomixis is advertised by a permanent cyst. As we have seen, when the organism emerges from its cyst it is young, labile and vigorous.

The changes in organization which have been described thus far are all normal reactions to the protoplasmic activities going on within the organism. They are repeated by every individual of the species and follow the same sequence in a normal life history. They represent, therefore, the complete normal expression of the potentialities of a given organization, called forth by the chemical and physical interactions of the constituent substances in protoplasm and by the interactions of these substances with the environment. Renewal of vitality, which accompanies reorganization, may be brought about by division, by fertilization or by parthenogenesis. Some of the processes may be inhibited by changes in the environment or some may be hastened by appropriate changes. Thus the onset of conjugation may be induced by certain salts in the medium according to the experiments of Zweibaum, of Jollos, of Baitsell and others.

Now the interesting problem arises: Is it possible to so modify the environment that the fundamental organization of a protozoön becomes permanently changed and in such a way that variations in the derived organization are produced which will be perpetuated? A great many experiments have been undertaken in connection with this problem, some dealing with modifications of the environment, some with modifications of the protoplasm itself. The general result of all such experiments has been to demonstrate the extreme difficulty with which the protoplasmic organization can be changed in any permanent way. Let me cite a few examples to illustrate this difficulty.

In nature there are many cases in which change in environment has not resulted in a permanent change in the organization. Thus a drastic change in environment is introduced when the malaria-causing organisms *Plasmodium* and *Haemoproteus* species are inoculated by their definitive hosts, mosquitoes, into human or bird blood. An entirely new series of reactions and structures are expressed by the old organization and the change is persistent

so long as the parasites remain in the new environment. But the change is not permanent and some of the fundamental and necessary processes for continued life of the parasites are apparently impossible in the vertebrate hosts. For these the parasites must return to the mosquito. Many analogous instances might be given. The vegetative life of the Coccidian *Aggregata eberthi* is passed in the intestine of crabs; but for full development such crab parasites must be taken up by cephalopod molluscs; the giant gregarine *Porospora* has no permanent organization as such in the digestive tract of the lobster, but ultimately dies if not swallowed by the mussel *Mytilus*. It is probable that complete adaptation and a permanent change in organization is represented by the great majority of gregarines, coccidia and neosporidia which undergo their full cycle of development, sexual and asexual phases, in the same host.

Human experiments of analogous type have been less successful than these natural ones. It is quite possible to apparently change the organization by changing the environment. *Amoeba verrucosa* of fresh water becomes quite a different type of organism when transferred to sea water and will reproduce this type as long as it is kept in sea water. But transfer it back to fresh water and its organization will be found to have lost none of the characteristics of *Amoeba verrucosa*. The genotype is unchanged. In a similar way organizations of different species when subjected to chemical or temperature changes of the medium may be gradually educated to perform their vital activities while in the changed environment. We call it adaptation and we are only beginning to realize the possibilities of protozoon organizations to adapt themselves to such changed conditions. But the changes are not permanent; they are what Jollos has aptly termed *enduring modifications,* and in the majority of cases restoration to their habitual environment restores their usual organizations. With parasitic forms so-called poison-fast races have been known for years. Atoxyll-fast or arsenic-fast Trypanosomes, mercury-fast spirochetes are examples of such adaptations to poisons. Quinine-fast Plasmodia are probably responsible, as Bignami first pointed out, for enigmatical relapses in malaria. In all such cases, again, reversion to the normal occurs with restoration to the usual media or to the definitive host. In some cases these changes involve structural modifications which are visible. Thus Werbitzki obtained trypanosomes without the usual parabasal body by adding pyronin to the culture medium and after the treatment had been stopped such races lived for many generations of transplants with no trace of this kinetic element. Ultimately, however, with passage of these trypanosomes through the invertebrate host, the parabasal body reappeared. A very amazing result has been obtained recently by Hartmann with *Eudorina elegans,* a 32-celled globular colony, and with *Gonium pectorale,* a 16-celled flat colony. By the addition of nitrogen salts, particularly ammonium chloride, to the medium he changed *Eudorina* into *Gonium;* and a normal *Gonium* into a *Eudorina*. Here was a complete change in organization, so complete indeed that two widely different genera were interchanged. But the change lasted only so long as the unusual salts were in the medium and if the interchanged genera were replaced in normal pond water, each reverted to its characteristic organization.

In another group of experiments attempts are made to change the organization while the environment remains normal. Here, again, as with the preceding group, the organization in the majority of cases is not permanently altered.

Such experiments may involve the cytoplasm alone or the nucleus; if the latter, there is some evidence of permanency; if the former, no evidence at all. Thus mutilations are passively handed down to progeny by division. We may cut a *Paramecium* through the anterior or the posterior third; the cut surface is soon replaced by normal cortex, but the cell is truncated and quite unlike the normal. When it divides it forms a small truncated cell and a full-size normal cell. The normal cell continues to form normal cells by division and the truncated cell in the majority of cases will continue to form one normal and one truncated individual for three or four generations, but there is a gradual regeneration of the lost part until finally the original truncated cell gives rise to perfect cells. In some cases, however, such truncated cells have lost something in the organization that is essential for reproduction. They will grow and attempt to divide, but division is incomplete and a monster results. Repeated abortive attempts to divide result in the formation of many mouths and peristomes; in one such monster I counted eighteen mouths. Such things may live for weeks, but they ultimately die. In such cases we succeed in mutilating the organization to such an extent that normal coordinations are lost and a return to the normal is impossible. Similar monsters are characteristic of old-age cultures of ciliates.

Artificially produced spines or processes or clefts in the cortex may be handed down passively to descendants by division, but such mutilations are soon healed, leaving no trace of their former existence, and no change in organization.

Or it is possible to change the relative proportions of substances in the organization. Popoff, for example, centrifuged a *Stentor* when about to divide producing individuals in which the original beaded nucleus was unequally distributed, one individual receiving sixteen beads, another only three. Both reorganized perfectly, but the second individual was only one quarter the size of the first. After a few days both individuals had the same number of beads. In another case a dividing *Stentor* was suddenly cooled so that the division processes stopped and the normal form was resumed. Replaced in its normal medium it became a giant *Stentor* and a temporary race of giants was formed by division. An analogous experiment was made by Chatton on the ciliate *Glaucoma scintillans*. By treating individuals in the early phase of division with dilute solutions of sodium bromide for a few minutes and then replacing them in their normal medium he obtained individuals with two complete sets of cellular organs, two mouths, two peristomes, two vacuoles, etc., but with only one macronucleus. These double individuals upon division produced similar double individuals and continued to do so for a period of five months when the culture was abandoned. Analogous double individuals obtained by Dawson were fused back to back and in one culture such a pair of *Oxytricha hymenostoma* was carried through 102 generations by division. A third illustration occurred in a culture of *Uroleptus mobilis*. Two individuals not only failed to separate after conjugation and subsequent reorganization, but fused throughout the entire length of the body, forming a single bilaterally symmetrical individual with two complete sets of cellular organs. It reproduced through 367 generations by division and lived more than fourteen months. Here there was a distinct change in organization and a change whereby some of the diagnostic features of *Uroleptus* were lost and new features formed. Thus the macronucleus became so modified that it would not be recognized as a *Uroleptus*

nucleus, becoming a broken ellipse in form. With the novel organization, however, was a limitation of function. The double organism had apparently lost the power to encyst; nor would the most tempting conditions of the environment induce them to conjugate. The principle of monogamy had been apparently established in one case at least of the ciliates, but it was fatal; the two individuals lived together and they died of old age together, a beautiful Darby and Joan existence.

The upshot of all such observations and experiments is the demonstration that the organization of these unicellular organisms is fixed for each species and can not be altered in any permanent way by crude artificial changes of the environment or by any equally crude mutilation of the protoplasmic architecture. The permanent changes that occur come from within the organization itself.

The variations that arise from within the organization may be induced or at least furthered by external help from the investigator. Thus Jollos found that variations in function and structure of *Paramecium* could be established by treatment with arsenic acid or with high temperatures, provided these abnormal conditions were introduced at what he calls the "sensitive period" immediately after conjugation. Thus immunity to high percentages of arsenic and increased size of the cell were conditions which persisted through several successive periods of endomixis and through two successive conjugations. In these respects it appears that Jollos has come rather close to producing mutations. A more definite mutation has recently been observed by Professor Mary S. MacDougall. In a pure line of *Chilodon uncinatus* she observed that the usual form was being replaced by a larger and a sturdier race of *Chilodons* but with structures otherwise of *uncinatus*. Cytological study of these forms, particularly during conjugation and division, showed that the ordinary diploid race of *Chilodon* was the original race under cultivation and was characterized by four chromosomes, while the new race was a tetraploid form with eight chromosomes. Here a change in organization had been effected by a change in one of the fundamental components of the protoplasmic make-up. Under what conditions, how or when the change occurred is entirely unknown.

Still another method of obtaining well-marked variations in organization is the method of selection. The splendid work of Jennings and his associates along this line has demonstrated that the sifting out of germinal characteristics and establishment of definite and varied types of structure through uniparental inheritance is no theory but a fact established by patient research. In this connection I need only recall the work of Jennings on *Difflugia corona;* of Hegner and of Reynolds on *Arcella* and of Root on *Centropyxis*. Whether or not, as Jollos points out, such variations represent a permanently changed genotype can not be determined from any of this work. For such determination we must have the results of reorganization which follow the fertilization of gametes from gametocytes of a given selected line.

We have little doubt, *a priori*, that variations may and do arise from the union of germ plasms in Protozoa as in Metazoa. But there is singularly little evidence of this along experimental lines that will bear analysis. I am aware of only one experiment that will stand the test of criticism and even this should be confirmed before we can accept it as conclusive. I refer to the experiments on Mendelian segregation in the hands of Adolph Pascher, who succeeded in crossing two incompletely identified species of *Chlamydomonas*. Of the four products of the zygote, one was like species A, one like species B and two had new

organizations representing diverse combinations of characters of A and B. Here again was evidence of the sifting out of germinal characters presumably by zygotic meiosis and with such germinal sorting the origination of new types of organization.

In conclusion, I would point out once more that organization in Protozoa is as definite and as fixed as it is in any type of living things; that it is represented by visible structures which are not only temporary but are subject to changes with metabolic activities. These visible structures are replaced and formed anew at conjugation or fertilization generally or by parthenogenesis; and they are formed anew at periods of cell division. With fertilization, with endomixis, and with cell division there is evidence that the cell is completely reorganized and that the fundamental, invisible, organization starts with a clean slate after each and every one of these deep-seated phenomena.

I have also endeavored to show that gamete formation and the period of maturity in ciliates is evidence of a cumulative differentiation of the protoplasmic substances; that gametes are so modified that without fertilization or its equivalent they can not live and that ciliates without conjugation or endomixis in the majority of cases will live only with weakening vitality which ends in death.

Finally let me repeat once more: what we ordinarily mean by the term "life" is protoplasmic organization. Just what this is we do not know; it can not be measured with our present means of measurement; it is continuous and has been continuous since the remote past and will continue indefinitely in the future. Vitality is the activity of the organization; it can be known and measured; it is known and measured in large part; it is discontinuous. Death is not of necessity the cessation of vitality; death occurs only with disintegration of the machine. When this occurs with any single individual acting as trustee for the specific organization, there are myriads of other trustees which will carry that organization on and into the future.

RADIO TALKS ON SCIENCE[1]

THE ETHER-DRIFT EXPERIMENTS OF 1925 AT MOUNT WILSON

By Professor DAYTON C. MILLER

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THE general acceptance of the theory that light consists of a wave motion in a luminiferous ether made it necessary to determine the essential properties of the ether, which will enable it to transmit the waves of light and to account for optical phenomena in general.

Several physicists have sought to prove the existence of a stationary ether by direct experiment. The most fundamental of such proposals was that of Professor A. A. Michelson, made in 1881, based upon the idea that the ether as a whole is at rest and that light waves are propagated in the free ether in any direction and always with the same velocity with respect to the ether. It was also assumed that the earth in its orbital motion around the sun passes freely through this ether as though the latter were absolutely stationary in space. The experiment proposed to detect a relative motion between the earth and the ether, and it is this relative motion which is often referred to as "ether-drift." A remarkable instrument known as the "interferometer," which has been invented by Professor Michelson, is capable of detecting a change in the velocity of light of the small amount involved in ether drift.

In the year 1887, at Case School of Applied Science, in Cleveland, Professor Michelson, in collaboration with the late Professor Edward W. Morley, of Western Reserve University, made certain important developments of method and apparatus and used the interferometer in the now famous "Michelson-Morley Experiment," in an effort to determine whether the motion of the earth through space produces the effect upon the velocity of light as predicted by theory.

In November, 1887, they announced their conclusions as follows: "Considering the motion of the earth in its orbit only . . . the observations show that the relative motion of the earth and the ether is probably less than one sixth of the earth's orbital velocity and certainly less than one fourth."

In 1895 Lorentz and FitzGerald suggested that the motion of translation of a solid through the ether might produce a contraction in the direction of the motion, with extension transversely, the amount of which is proportional to the square of the ratio of the velocities of translation and of light, and which might have a magnitude such as to annul the effect of the ether-drift in the Michelson-Morley interferometer.

The writer, in collaboration with Professor Morley, constructed an interferometer about four times as sensitive as the one used in the first experiment, having a light path of 224 feet, equal to about 150,000,000 wave lengths. Such an instrument with a base made of planks of pine wood was used at Cleve-

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of W. E. Tisdale.

land, in 1902, 1903 and 1904, for the purpose of directly testing the Lorentz-FitzGerald effect, but the changes in the wooden frame due to the variations in humidity and temperature made accurate observations difficult to secure. A new supporting frame was constructed of structural steel and was so arranged that the optical dimensions could be made to depend upon distance-pieces of wood, or upon the steel frame itself. Observations were made with this apparatus in 1904. The results were expressed as follows: "If the ether near the apparatus did not move with it, the difference in velocity was less than 3.5 kilometers a second, unless the effect on the materials annulled the effect sought. Some have thought that this experiment only proved that the ether in a certain basement-room is carried along with it. We desire to place the apparatus on a hill, covered only with a transparent covering, to see if an effect can be there detected."

In the autumn of 1905, Morley and Miller removed the interferometer from the laboratory basement to a site on Euclid Heights, Cleveland, at an altitude of about three hundred feet above Lake Erie, and free from obstruction of buildings. Five sets of observations were made in 1905–1906, which give a definite positive effect of about one tenth of the then "expected" drift.

It was at this time that Einstein became interested; and in November, 1905, he published a paper on "The Electrodynamics of Moving Bodies." This paper was the first of a long series of papers and treatises by Einstein and others which has developed into the present theory of relativity. In the first paper, Einstein states the principle of constancy of the velocity of light, postulating that for an observer on the moving earth, the measured velocity of light must be constant, regardless of the direction or amount of the earth's motion. The whole theory was related to physical phenomena, largely on the assumption that the either-drift experiments of Michelson, Morley and Miller had given a definite and exact null result.

The deflection of light from the stars by the sun, as predicted by the theory of relativity, was put to the test at the time of the solar eclipse of 1919. The results were widely accepted as confirming the theory. This revived the writer's interest in the ether-drift experiments, the interpretation of which had never been acceptable to him.

The site of the Mount Wilson Observatory, near Pasadena, California, at an elevation of about six thousand feet, appeared to be a suitable place for further trials. An elaborate program of experimentation was prepared.

Observations were begun in March, 1921, using the apparatus and methods employed by Morley and Miller in 1904, 1905 and 1906, with certain modifications and developments in details. The experiments have been continued till the present time.

Throughout all these ether-drift experiments, at Cleveland and at Mount Wilson, there persisted a small but very *definite positive effect*. In spite of long-continued efforts it was impossible to account for these effects as being due to terrestrial causes or to experimental errors. Very extended calculations were made in the effort to reconcile the observed effects with the accepted theories of the ether and of the presumed motions of the earth in space. The observations were repeated at certain epochs to test one after another of the hypotheses which were suggested. At the end of the year 1924 a solution seemed impossible.

Previous to 1925, the Michelson-Morley experiment has always been applied to test a specific hypothesis. The only theory of the ether which has been put to the test is that of the absolutely stationary ether through which the earth moves without in any way disturbing it.

To this hypothesis the experiment has given a negative answer. The experiment was applied to test the question only in connection with specific assumed motions of the earth, namely, the axial and orbital motions combined with a constant motion of the solar system towards the constellation Hercules, with the velocity of nineteen kilometers per second. The results of the experiment did not agree with these presumed motions. The experiment was applied to test the Lorentz-FitzGerald hypothesis; that the dimensions of bodies are changed by their motions through ether; it gave a negative answer to this. It has been applied to test the effects of magnetostriction, of radiant heat and of gravitational deformation of the frame of the interferometer. Throughout all of these observations, extending over a period of years, while the answers to the various questions have been "no" there has persisted a constant and consistent small effect which has not been explained. Not until the present year, 1925, has a general question, not based upon a specific hypothesis, been put to the test.

The ether-drift interferometer is an instrument which is generally admitted to be suitable for determining the relative motion of the earth and the ether, that is, it is capable of indicating the direction and the magnitude of the absolute motion of the earth and the solar system in space. If observations were made for the determination of such an absolute motion, what would be the result, independent of any "expected" result? For the purpose of answering this general question, it was decided to make more extended observations and this was done in the months of March, April, July, August and September, 1925.

The observations made at Mount Wilson in 1925 are more than twice as numerous as all the other ether-drift observations made since the year 1887. The total number of observations made at Cleveland represent about one thousand turns of the interferometer, while all the observations made at Mount Wilson previous to 1925 correspond to one thousand two hundred turns. In 1925 observations consist of four thousand turns of the interferometer, in which over one hundred thousand readings were made. This required that the observer should walk, in the dark, in a small circle, for a total distance of one hundred miles, while making the readings.

The ether-drift experiments at Mount Wilson lead to the conclusion that there is a definite displacement of the interference fringes of the interferometer corresponding to a relative motion of the earth and the ether at this observatory of approximately ten kilometers per second. In order to account for these observations as the result of an ether-drift it is necessary to make two assumptions; first, that there is a constant motion of the solar system with a velocity of two hundred kilometers per second or more towards a point in the constellation Draco, near the pole of the ecliptic and having a right ascension of 262° and a declination of +68°; second, that, in effect, the earth drags the ether so that the apparent relative motion at the point of observation is one twentieth of the absolute motion, and that this drag also displaces the apparent azimuth of the motion about 45° to the westward.

The first assumption as to the magnitude and direction of the motion is in general agreement with indications obtained by other methods. The study of the proper motions of the stars and also of the motions in the line of sight lead to the conclusion that the sun is moving towards the constellation Hercules in a direction having a right ascension of 270° and a declination of +33° with a velocity of 19 kilometers per second. Dr. Strömberg finds from a study of star clusters that there is a motion of our cluster in the direction having a

right ascension of 307° and a declination of +56°, the velocity being three hundred kilometers per second. The three determinations of the absolute motion of the system are thus all in the same general direction and lie within a circle having a radius of 26°. The assumed velocity of two hundred kilometers per second is about seven times the orbital velocity of the earth and it is of a reasonable magnitude. This first assumption, therefore, seems to offer no difficulty.

The second assumption that there is a drag of the ether by the earth involves a considerable readjustment of the theories of the ether, inasmuch as it requires a modification of the accepted explanation of aberration. In commenting on the preliminary report of this work presented to the National Academy of Sciences in April, 1925, Dr. L. Silberstein said: "From the point of view of an ether theory, this set of results, as well as all others previously discovered, are easily explicable by means of the Stokes ether concept, as modified by Planck and Lorentz, and discussed by the writer (Silberstein) in the *Philosophical Magazine.*"[2]

It has been stated by Eddington that the results of the Mount Wilson ether-drift observations would require star places observed on the mountain and at sea level to differ by 7″ of arc. This statement is based upon the presumption that the ether-drift would have a zero value at sea level. No observations have ever been made at sea level and the indications are that the value of the drift in such a location would be only very slightly less than that observed on Mount Wilson; thus the difference in observed star places would be of the order of one second of arc. Systematic differences in standard star places as determined at different observatories have been noted. The so-called constant of aberration as now universally applied in astronomical calculations does not have a value determined directly from experiment.

All these effects might be explained on the hypothesis of a variation in ether-drift due to differences in the local coefficient of drag. The drag at any given station may be dependent upon altitude, local contour and the distribution of large masses of land such as mountain ranges; the effect may be likened to ordinary refraction, with the interferometer measuring the index of refraction which has a magnitude of the order of 10^{-9}.

The reduction of the indicated velocity of two hundred or more kilometers per second to the observed value of ten kilometers per second may be explained on the theory of the Lorentz-FitzGerald contraction without assuming a drag of the ether. This contraction may or may not depend upon the physical properties of the solid, and it may or may not be exactly proportional to the square of the relative velocities of the earth and the ether. A very slight departure of the contraction from the amount calculated by Lorentz would account for the observed effect. A reexamination of the Morley-Miller experiments of 1902–1904 on the Lorentz-FitzGerald Effect is now being made, with the indication that the interpretation may be modified when taken in connection with the large velocity of the solar system indicated by the observations of 1925. A definitive numerical calculation will require several months of continuous work and is now in progress.

[2] February, 1920, Vol. 39, page 161.

RADIO COMMUNICATION WITH SHORT WAVES

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THE radio art had its genesis in the experiments of Hertz in Germany in 1885. Hertz used waves of very short length, namely, in the neighborhood of the band from one and a half to three meters. The first radio signals, which could scarcely be called messages, were sent across a room in a physical laboratory. The region in which waves were studied rapidly extended from a few meters to several thousand meters in wavelength.

The experiments of early investigators have been forgotten by many, but within the last three years some very remarkable results have been obtained as the outcome of studies of communications on short waves, which, although not quite as short as those used by Hertz, are nevertheless of the same general order of magnitude. I refer in particular to wavelengths in the band between ten meters and one hundred meters. The early experimenters had neither adequate devices for detecting short waves nor means of producing short waves conveniently with any considerable amount of energy. Indeed, until the invention of the vacuum tube transmitter it would have been utterly impossible by any means known to the art to produce short wave radiation of strength sufficient for experiments at any distance. In the meantime the art had naturally extended itself into the range of longer waves where greater energy could be produced and there were many things to be done in this line of development.

The United States Navy had been using as far back as 1917 or 1918 waves as short as one hundred and fifty meters and sometimes one hundred and twenty-five meters, but only for communication at short distances within the fleet. Aside from this limited use of fairly short waves by the navy, comparatively no use was made in this country of waves shorter than two hundred meters. All waves shorter than two hundred meters were considered worthless for reliable long distance work.

In the early days of amateur radio communication, the amateurs operated on a great variety of wavelengths, but they were restricted when government regulations finally stepped in, in the interest of avoiding interference. Operating in the two hundred meter band, the amateur stations of five to ten years ago established many remarkable long distance transmission records, but it was found upon analysis of these records that very few transmissions were recorded for distances over 150 miles by daylight and that the nocturnal transmissions were extremely erratic and unreliable. Indeed, they were so uncertain that the military and commercial interests of this country were well satisfied that they were not in this wave band. For a number of years no one thought seriously of attempting long-range experiments on still shorter waves because as one studies the behavior of transmissions from fifteen thousand meters down to two hundred meters, it is easy to see that the daylight ranges rapidly decrease and that the night ranges become more and more erratic and unreliable. However, the amateurs of this country made a strenuous and concerted effort to get signals from this country into Europe with low power transmitters operating in the two hundred meter band, but the experiments were attended

only with a very limited amount of success.

Somewhat later experiments were undertaken in the neighborhood of one hundred and five to one hundred and ten meters which showed entirely different results. The experiments by American amateurs are of particular interest because they were carried out, in most cases, with less power in the transmitting antenna than would be required to operate an ordinary electric flatiron and yet several of them were able to put signals into Europe consistently for a good many hours at a time and for many nights in succession. The behavior of these waves in the neighborhood of one hundred meters was a distinct reversal of form and exactly the opposite of what would have been expected by every one familiar with the developments in the longer wavelengths. Instead of signals being of less intensity than those sent out on two hundred meters with the same power, they were of much greater intensity, and instead of being more unreliable they were a great deal more dependable. The success of the American amateur in bridging the Atlantic even if only during the night hours with a ridiculously small amount of power, opened the eyes of the whole world to new possibilities in short-wave communication. From that time on, the development has been extremely rapid, and in this new development the technical staff of the Naval Research Laboratory, located in the southern end of the District of Columbia, has played no inconsiderable part. For more than a year one of the transmitters, built at this laboratory and placed at the disposal of the Navy Department during the night hours, has carried almost the entire night load of our high-powered station at Annapolis which has resulted not only in the saving of a considerable sum of money for the navy, but has relieved broadcast listeners in Baltimore, Washington and Annapolis of the extremely disagreeable radio interference which emanated from the high power, long-wave station at Annapolis.

From the point of view of my listeners one of the greatest advantages of the use of short waves is in the enormous reduction of interference which is to be expected as the new short wave stations are developed and gradually take over work during broadcast hours at least.

The Naval Research Laboratory has just completed an investigation of the conditions of broadcast reception within half a mile of our most powerful transmitter and it has been found that a moderately selective receiver of the type not making use of any oscillating tubes shows no serious amount of interference even if as close as half a mile. The interferences which will occasionally be observed, although they are very rare indeed, from short wave transmitters, generally are not the result of the high frequency transmitters themselves, but are due either to a very non-selective receiver or to a combination of a number of other transmissions from different sources with the short-wave transmission. This sort of combination is not peculiar to high frequencies but can occur in any powerful transmission. Investigations have proceeded far enough to state definitely that the interference from the transmitters used at the Naval Research Laboratory on high frequencies in communicating with the commander-in-chief of the United States fleet during the Australian cruise, and which had no difficulty in putting signals directly into New Zealand and Australia, nine thousand to ten thousand miles, respectively, is not nearly so great an interference by a factor of many times as the interference which would have been experienced from a long-wave transmitter which at best would not have been capable of handling similar traffic much further than the Pacific coast.

A very great change in the nature of the observed effects occurs as the waves are shortened still further, and it would appear from theoretical considerations which have been published in "QST" for October, 1925, and which will be published in the February issue of *The Physical Review,* that waves much shorter than fourteen meters will not be of much use for really long-distance work. Even in the band between twenty and forty meters, a new phenomenon occurs which we call the skip distance effect. It is now definitely known that the wave directly radiated from the antenna and spread out over the ground in the usual manner is very quickly absorbed and is of no use in long distance work. On the other hand, the portion of the rays which radiate up slantwise towards the sky from the antenna are refracted from an ionized region whose height varies from fifty to seven hundred miles according to the time of the year and time of the day, and these rays coming down to earth again after a considerable distance are the ones which are valuable in communication. Under certain conditions, when operating in the band from twenty to forty meters, stations at relatively nearby points—that is, a few hundred miles away—will be skipped over or missed entirely, whereas very intense signals will be received much further on. This effect naturally was very puzzling before it was understood. I can recall an occasion when I was in communication on the twenty meter band with a British station between twelve and one in the afternoon: at the same time, two American amateurs, one in St. Paul, Minnesota, and one in Connecticut, were listening in on the test. The only way I could communicate with the man in Connecticut was to relay a message either through St. Paul or through London. He was unable to hear my signals, and I was unable to hear his. On the other hand, I was perfectly well able to work London. The St. Paul man, on the other hand, being outside the skip distance, which at that time of the year was about five hundred miles for that wave, was able to communicate with everybody. Now during the night hours the skip distance is very great indeed. I have communicated directly with Sydney, Australia, in the twenty meter band without having my signals heard anywhere in the United States outside of the eight or ten miles which would be penetrated by my rapidly absorbed ground wave.

It is a common experience at this time of the year when operating in the forty-meter band, to notice that as the ionized layer of the earth's atmosphere rises to high altitudes after sunset, the skip distance is increased so that the New England stations become gradually weaker as the night hours wear on and disappear at Washington, but at the same time European stations working in this band and our midwest and West coast stations, to say nothing of New Zealand and Australia, come in very well indeed. It is due to the use of the "sky wave" (as it has been termed by Mr. Alexanderson) which passes through a medium not capable of absorbing it, that such immense distances can be covered with such a small amount of power. Communication between the United States and Australia has been maintained on a number of occasions by American amateurs using only a few watts; in other words, much less power than is required to light a twenty-five-watt electric lamp. I do not say that communication was fully reliable with such power, but nevertheless a number of messages have been thus exchanged.

One result of the short-wave development has been the eager entry of amateurs in almost every country of the world into the transmitting game. This brings its troubles and makes necessary very careful government supervision to prevent trespass upon bands allotted to

the government and commercial activities. On the other hand, however, this has given the radio art a tremendous advance and it has permitted the forming of almost countless international acquaintances. It is not at all uncommon these days to listen in on conversations between South Africa and New Zealand, or between Great Britain and America, or between France and South America. I have known an American amateur to communicate with amateurs of three or four different nationalities in one evening. I do not need to tell you that all this is bringing the world closer together and helps people who are geographically far apart to understand each other better, which is one of the best ways to reduce the chance of armed conflicts in the future.

Another very interesting thing has come out of the short-wave development, and that is, that it is entirely possible to receive a radio signal on short waves over greater distance than one half way around the world. Knowing the properties of these waves, we can definitely say, if Johannesburg, South Africa, hears one of our west coast stations at a time of the day when there is nine hours of daylight between that station and Johannesburg, that a forty-meter wave could not possibly have traveled such a distance during daylight, therefore it must have gone the other way around the world, namely, a distance of sixteen thousand miles.

Sometime when the conditions are just right, it should be possible to locate a receiving station within the skip distance of a transmitter operating on very short waves, and to receive a signal from that transmitter after it has traveled completely around the world.

I am the last person to minimize the great value of broadcasting as it exists to-day. Some of you in the old days long before the existence of WCAP or WRC remember the pioneer work done by NSF and NOF, which stations were operated by the navy under my direction and were the first stations in the world to broadcast a presidential speech and various addresses by cabinet members, members of Congress and other officials, and also the first to put on the air the U. S. Navy Band and the U. S. Marine Band. Nevertheless, I believe that the short wave experiments under way these days bringing the peoples of the world so much closer together are of equal importance with broadcasting. They are indeed closely connected with projects of international broadcasting because the link between countries far distant from each other which permits the transfer of foreign programs through our stations is the short wave transmitter.

SOME COLD WAVES OF GEOLOGIC HISTORY

By Dr. DAVID WHITE

CHAIRMAN OF THE DIVISION OF GEOLOGY AND GEOGRAPHY OF THE NATIONAL RESEARCH COUNCIL

THE climatic abnormalities of 1925 and 1926 will long be remembered; late autumn skating in England and snows and floods in France and sunny Italy; mild weather, suggesting spring, in the Siberian winter, and frightful storms over the North Atlantic; two ocean currents shift their courses slightly, and green fields wave on the west coast of Peru where a desert climate of forty

years between rains is said normally to prevail.

Meanwhile, Dr. C. G. Abbot, of the Smithsonian Institution, insistently reports that for three years, ending last summer, the heat given off by the sun has been 2 per cent. below the average in amount. Some sort of weather upset was bound, he says, to take place somewhere on the face of the earth, but not everywhere. Dr. Abbot does not say where.

After all, however, the cold waves—even the consolidation of all the cold waves and storms of the winter—are insignificant in comparison with the winters of the glacial period. I refer, of course, to what geologists call the Glacial Age of the Pleistocene. This was a period of extraordinary weather, during which, at as many as five different times, great ice sheets, thousands of feet in thickness, spread from the north and northeast over northeastern America, as far south as Kansas, Kentucky and New Jersey. Four such ice caps were developed in northwestern Europe, while Antarctic lands also were more deeply ice-buried than now. In the Sierra Nevada in California, some of the ice tongues, creeping down in the valleys, were over sixty miles in length.

The areas covered by these great ice sheets did not fully coincide, for the earlier ice extended farther to the southwest; but for the most part they overlapped. Over four million square miles of the mainland of this continent was ice-covered.

The glacial period as a whole was almost certainly over six hundred thousand years long, but the interglacial portions, the intervals between the several ice sheets, occupied most of the time, being very much longer than the durations of the ice. During some of the earlier interglacial intervals, one of which was probably two hundred and fifty thousand years long, the climate in the glaciated regions was much warmer than it is to-day.

Before these vast devastating ice invasions took place, with drastic climates extending far beyond the borders of the regions actually covered by the ice, representatives of the rhinoceros, camel, llama, lion, tiger, horse, tapir, mastodon and elephant roamed in different parts of what is now the United States. Also not less than ten kinds of horses were present. Some of these animals survived the first and even the second or third of the great ice invasions, but none of them, except the elephant and the mammoth, seem to have been here when the last—the great Wisconsin ice sheet, which covered all New York, New England, Michigan, Wisconsin and northern Pennsylvania, as well as most of Ohio, Indiana and Illinois—began its retreat. During these prolonged cold waves, musk oxen pastured in Utah, Oklahoma, Arkansas, Ohio and Pennsylvania; the northern or woolly mammoth strayed south of the Potomac River, and walrus sported in the water off the New Jersey coast. The horse, you will remember, has been brought back to America by the white man.

In cave earth, fallen into an old sinkhole near Cumberland, Maryland, during one of the warm interglacial intervals, Dr. Gidley, of the National Museum, found many extinct animals, including a tapir, a crocodile, a peccary and an eland, the latter hardly distinguishable from the eland now living in Africa. This most striking aggregate, including animals no longer living on this continent, is bound to set us thinking about the changes of climate and the intercontinental land connections which made it possible for these creatures to meet together and live near the present southern border of Pennsylvania. A few other discoveries, hardly less remarkable, have been made in other portions of the country, but the wealth

of information regarding the climatic changes and the distribution of animals and plants in this very recent time to be gained by the systematic search of cave deposits is still almost untouched. This fascinating field of investigation, which may yield surprises in the way of human remains also, is greatly neglected in America. It invites attention.

It is remarkable that these great changes in climate and life should have taken place so recently, for geologists tell us that while the first of the ice sheets formed over half a million years ago, the last great ice sheet, the Wisconsin, began its backward thaw only seventeen thousand or perhaps twenty thousand years ago. In fact, if all geologic time were but one day, the events of the last glacial period would all have taken place within the last fifteen or twenty seconds, or while I am saying it.

The Pleistocene glacial period is most interesting to us because it is so realistic and close; because the tracks left by the Wisconsin ice sheet are so conspicuous and have neither decayed nor been covered by deposits of a later epoch, and because the movements of the ice and the fluctuating climates determined to a large extent the composition of the animal and plant life which we now see about us.

However, this period of Pleistocene glaciers and warm interglacial intervals was neither the first nor the greatest of the great ice ages of geological history. Periods of far more sensational climatic phenomena occurred both in early Permian time, which is rather far back, and in that period extremely remote, even from the geolcgic viewpoint, known as the Laurentian.

Permian glaciation was far more widespread than that of the Pleistocene, and, what is most remarkable, the ice developed in great sheets even within the tropics. Glaciers and, in some cases, ice caps, were present in tropical India, and in eastern South America to within ten degrees of the equator. All Africa south of twenty-two degrees seems to have been buried under ice which reached a thickness of four thousand feet. Icebergs spread thick mantles of glacial débris over the submerged portions of east, west and south Australia.

The Huronian glaciation was vastly more ancient even than the Permian. Ice-planed surfaces or moraines dating from the Huronian have been discovered in Ontario, Scotland, Scandinavia, India, China, Australia and in both equatorial and southern Africa. Measured by the new geological time scale which, as explained to the radio audience last winter by Professor Hess, is based on the rates of atomic disintegration of certain radioactive minerals in the earth, the Permian cold period should date back about seven hundred million years, or a thousand times further than the beginning of the Pleistocene glacial period, but the climatic severities of the Huronian took place probably as much as one billion five hundred million years ago. There were no vertebrates and no trees or other land plants in that ancient epoch.

Evidence of glaciation in some of the intervening geologic periods also is reported. These periods of minor and relatively local cold were the upper Devonian; the lower Carboniferous, when ice-borne boulders were scattered in eastern Oklahoma; and the Eocene, when glacial morainic deposits seem to have been laid down at moderate elevation in Colorado and Wyoming. Most of the vertebrate animals that were exterminated from this continent by the drastic climates of the Pleistocene were in process of evolution in the Eocene.

What were the causes of the periods of widespread cold, with the formation of continental ice sheets, at different regions of the earth? Frankly, we do not yet know. This is another question pressing for answer through research. If the observations by Dr. Abbot are

correct they point toward periods of deficiency in the amount of heat given off by the sun—which appears, in fact, to be a variable star—as possible causes of, or at least as important factors in causing glacial periods. A deficiency of so little as 2 per cent.—the rate of loss endured during the past three years—must produce appreciable results if it should be continued through a long term of years. A 5 to 8-degree Fahrenheit variation from the normal mean temperature distinguishes a very severe or a very mild season. A long-continued departure of 11 to 13 degrees on the side of coldness would probably bring glacial climate to many portions of the earth. Other suggestions proposed by different authorities are magnetic effects, volcanic dust and changes in the composition of the atmosphere. Glacial ice begins to grow where the accumulation of winter's snow and ice is ever so little beyond the thawing capacity of the average summer.

On the other hand, the determination of the climatic results of possible periodic variations in the sun's heat or the other possible causes—*i.e.*, the control of their expression in exaggerated heat or cold in one region or another of the earth and the localization of their concentrated effects—have to do with earth conditions, chiefly the relations, sizes and surface features of the continents and the seas. The essential controlling factors are the stages of emergence—the sizes and the shapes, the elevations, and possibly even the positions of the continents; the positions and relative heights of the mountain chains; the intercontinental connections, which have so often shifted in times past, and the corresponding sizes, shapes and connections of the oceans; the mutual relations between lands and seas; and finally, the densities, temperatures, volumes and velocities of the currents both of the ocean and of the air. These are the factors distributing, and to an extent, regulating the climates of to-day; they determine the regions of arid desert, of heavy rainfall, of fog belts, of dry winters, of maximum heat and of maximum cold; they order that Yuma shall be hotter than Savannah in the same latitude, and that the coldest spot in the northern hemisphere shall be in Yakutsk, Siberia, one thousand eight hundred miles from the north pole, rather than at the pole itself; and that Greenland shall be covered with an ice cap except at the extreme north end, which is cold enough but too dry, while the Pacific Coast climate of Alaska is surprisingly mild. Possibly glaciation on an extensive scale might be induced in some region simply by the coincident cooperation of favoring factors of land and sea.

It is the well-founded belief of oceanographers that weather in America is largely made at sea, in reaction to oceanic currents, as has just been witnessed off the Peruvian coast. It is said that if we had more exact knowledge of the width, depth, routes, velocities and temperatures of the sea currents, and especially of the nature and the results of changes in them, such as must be produced by changes in solar radiation, it would be possible not only better to understand the causes or sources of our atmospheric currents, but also to attain far greater success in weather prediction. When one recalls what stupendous benefits would be realized every year in agriculture, transportation, sea commerce, naval movements, aerial navigation, industry and even in recreation, by a gain of so little as 5 or even 3 per cent. in weather prediction, he wonders why some one does not make the requisite relatively small annual investment, through a term of years, in this field of scientific investigation. In view of the enormous stake, affecting every man, woman and child, and amounting to

colossal figures in dollars, it is remarkable that so little interest is taken in the scientific study of the weather, its causes, its history and the control of its changes.

Perhaps you say that ice caps still cover Greenland and Antarctica; that glaciers still survive in mountain regions; that present-day climate is abnormal and marked by extremes (which is true); and that if the time since the Wisconsin ice sheet thawed back is less than twenty thousand years, a mere fraction of the long intervals between some of the Pleistocene ice sheets, how shall we know that the glacial age is really past? May not another great ice sheet spread over northeastern America, burying the face of nature, especially if we should have a long period of deficiency of the sun's heat, combined with favoring continental and sea conditions? Really, no one knows the answer to this question. Lands and seas are ever changing; but some, at least, of the terrestrial climatic factors, such as changes in the shore lines and mountain elevations, now in progress point rather distinctly in the opposite direction. It seems probable that only some reversals of movement, which I have not now time to discuss, possibly combined with other causes, such as marked deficiency of solar radiation, could, in the course of a long time, bring on another great ice sheet.

PROGRESS AND PROPERTY

By EZRA BOWEN
LAFAYETTE COLLEGE

Older than incorporation, older than marriage, older than contract, older than religion—property is man's oldest institution: the right to use and enjoy to the exclusion of others is an expression of the instinct of self-preservation, and therefore as old as life itself.

"Primitive communism" is a myth. Overwhelming evidence points to its antithesis, primitive individualism, with an intense and violent sense of property—an instinct that antedates the appearance of man.[1] Caribou graze contentedly together, but only when there is wide pasture of so nearly equal quality that no part is worth claiming. Several hippopotami may bathe peaceably in one stream, but let that stream dry up, only a small pool remaining, and you will see in it one huge hippopotamus, enjoying exclusive bathing privileges. Finally, who will dispute the completeness of the property right of she-bear in her cave?

Social scientists have long held an opposite view, maintaining that "Everything was at first held in common,"[2] or "In the early stages of society the concept of private property is absent."[3] This view of private property would be correct were the pack stage of human development or the fortress-village stage really primitive, for in these two isolated and by no means primitive instances, some—though far from all—property was communized. But these two fear-engendered kinds of huddling are no more important in the evolution of human usage than are the whale and bat instances in the general biologic flow. The driving of one whole species of mammals into the mother waters and of another into that exclusively reptilian domain, the air, may be considered—are considered—purely sportive back-eddies in the widening flow of kinds.

Objects of primitive property were few, but it is a mistake to say "The concept of private property is absent"[4]—or even slightly developed. It is a mistake to say that the stone axe of a primitive chieftain, the only stone axe for miles around, was less of property, or even less property than a modern steamship. Property is a subjective matter.[5] Objectively, property was indeed inconsiderable in primitive times; but subjectively it was far more important than to-day. So sharp and clear was the concept of property that much (if not all) of man's belongings were buried with his body. That this nearly universal custom of primitive peoples was purely altruistic, that it came solely from a desire to provide the departed with equipment for a life to come, is a one-eyed view, a view that lacks perspective. More in accord with collateral facts is the explanation that a man's scant possessions were buried with him because

[1] C. Letourneau, "Property, Its Origin and Development," 1901.

[2] *Op. cit.*

[3] E. R. A. Seligman, "Principles of Economics," 1924. (The *law* of property was perhaps absent—unless common law in its nebular form, common usage, is meant—but the *concept* of private property was anything but absent.)

[4] *Loc. cit.*

[5] For may not any property relationship be altered, or even destroyed, without the slightest alteration or destruction of object or objective attribute? The war amendments to the American Constitution destroyed no black men, but they wiped out completely property in human beings.

they were *his*—so completely of him that they might possibly work a subsequent user harm. When Mr. Robert Dollar dies, his steamships will not be buried with him, nor any of his belongings; the concept of property has been sharply whittled down.

Property, then, was not built up to its present height from zero. On the contrary, its present level was reached by constant falling—and still it sinks.

Evolutionists find an additional hoop for their barrel in embryology; anthropologists and social-psychologists see one in the apparent connection between the mental history of mankind and that of a present-day pre-adult. Our theory of a direct relationship between the growth of civilization (and intelligence) and the expunging of the harder lines of private property finds similar reinforcement: A very small boy has a sense of property that is not soft. It is bounded by straight hard lines and the corners are very sharp. Sister may not have his drum—not even for a little while. She may not beat it, not even if she lets him hold it. May she tap it just once? No! An older boy owns a baseball, a bat and a glove. The boy next door wants the bat—not the ball and glove—just the bat. No, he may not have the bat. The neighbor's boy pleads for the ball. No, he may not have the ball. Well, then, just the glove? Again, no! With age and experience this propertied young man learns that he can profit by conceding some of his rights. And this whittling down of his concept of property progresses with years.

With the inception of intelligence and ability to measure sacrifice against corresponding gain, the institution of private property begins to lose its pinnacles and corners. And with every age and year, it wears smoother, rounder, smaller.

The past one hundred years have brought an onrush of civilization; the concept of private property has shrunk proportionately. The division of labor, that most fundamental and almost universal influence in social evolution, is an insatiable solvent of property. The inescapable concomitants of any division of task are cooperation and coordination: before them, exclusive rights of use and enjoyment have by necessity given away.

Escheat, the taxing power, eminent domain, the police power—especially the last three—are sledges that have struck away whole slabs of the Gibraltar of private property, making incessant and increasing inroads.

A farm, let us say, has been in your family for many generations. Over the week-end, you may have your friends for a clay-pigeon shoot, but not a live-bird shoot, though your father might. You may have a race-course on the place; you may not, however, set up betting booths, though your grandfather had that right. If a member of your family dies, you may not bury him on the place, but your great-grandfather might. If you raise rye, you may not build a still to make your rye into whiskey, though your great-great-grandfather had this right. These are rural examples of amended rights of use and enjoyment in land—all made under one power, the police or general-welfare power. But it is in urban property rights that this power has wrought its greatest havoc; and everywhere the powers of taxation and eminent domain have made even larger inroads.

You own a city lot, and you decide to put up a frame building on it. No, you may not; the law forbids because it would increase the fire hazard of your neighbors. Well, then, it will be of brick, a loft building. No; loft buildings are not permitted in that section of the city. Then you will build an apartment house, eighteen stories high. No;

buildings of more than six stories are forbidden in that zone!

In the same city you own a large section of water front, all on deep water; you own and operate many docks and piers; but they are not adequate to the needs of the city. The Board of Trade tells you that the city's life depends upon adequate port facilities, and urges you to furnish them. No, the docks and piers you have now do not pay—you will not build more. The next chapter is a sad one. The power of eminent domain is raised, a titanic lever. You and your property are pried apart. The city takes the property, and you a "fair consideration." Never will that water front again be private property.

Property is a right. As old as life, it is however wholly conventional—an artifice, an arrangement. Its purpose, its meaning, its end is to stimulate social, especially economic, activity. Where other motives, the desire to serve, the desire to emerge, the desire for activity itself—where these and other incentives work better, private property has been and will be further modified. Where the growing complexity and activity of society demand a more flexible arrangement, there too property has been and will be further modified.

You own property. Your rights in that property are less than those your father had in like objects; his rights were less than those of his father. Your son's rights will, in turn, be less than yours. Private property, the oldest and, at first, the most uncompromising of social institutions, tends to diminish in force and in scope with the growth of civilization.

THE MALE SEA DEVIL AND HIS WAYS

By Dr. DAVID STARR JORDAN

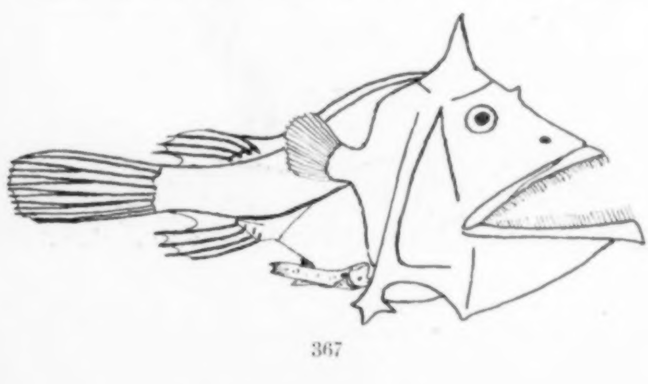
STANFORD UNIVERSITY

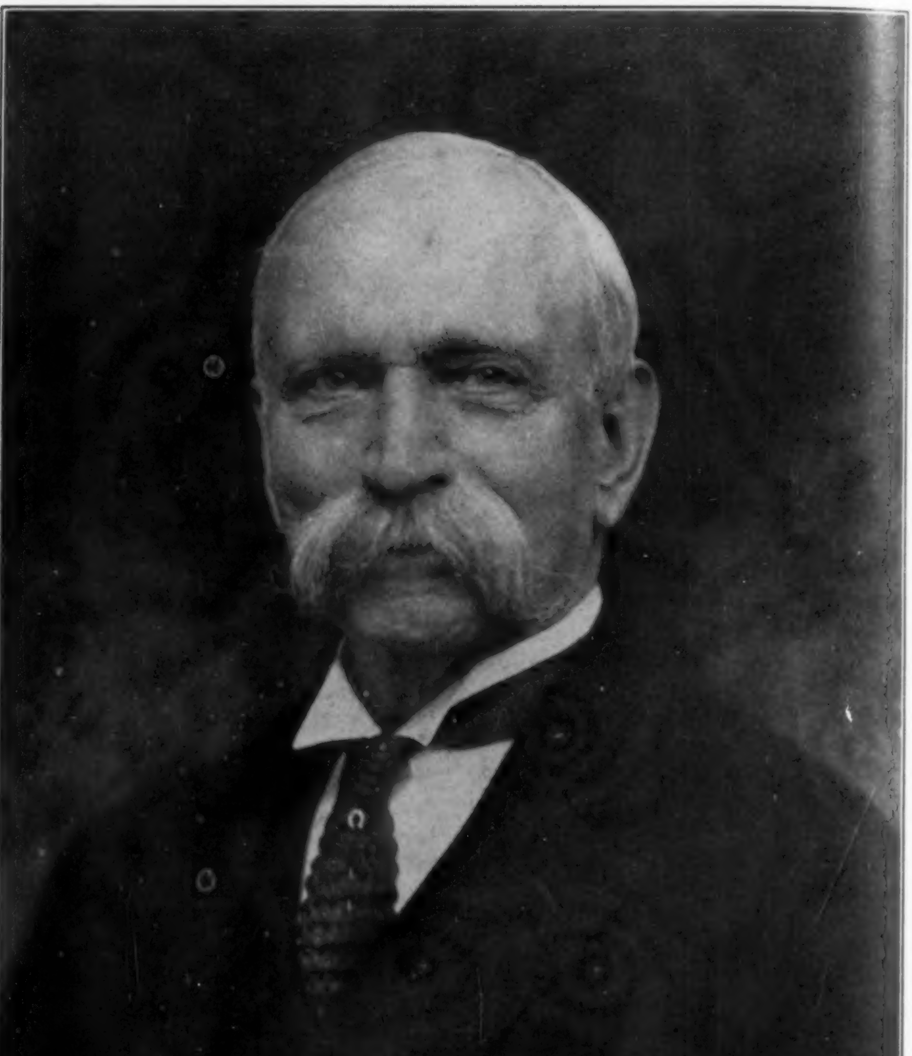
In a recent magazine, I gave an account of the capture of a very rare fish of the type known as Sea Devils, inhabiting great depths (2,500 to 6,000 feet) in the North Atlantic Ocean. Concerning this particular capture there were two very remarkable features, the one the fish itself, the other that the press account of it was absolutely correct. This particular Sea Devil is known as *Himantolophus grœnlandicus* and, like most of its associated devils, the first dorsal spine is separated, turned forwards over the mouth and provided with a luminous bulb at tip surrounded by fringes and which serves as a fish lure.

Some nineteen different types of sea devils (*Ceratiidæ* and *Himantolophidæ*) have been known, most of them from a few or sometimes but one specimen. All the examples hitherto known have been females more or less fully grown, no young having ever been seen, and until very lately no males. These fishes are "wide-ranging, solitary and sluggish, floating about in the darkness of the middle depths of the ocean."

Recently there have been received by the British Museum certain specimens which explain the absence of males. One of these was taken near Iceland, the others off Panama. All these have been described in detail by Mr. C. Tate Regan, of the British Museum. In all three of these, the male fish is a very small creature indeed, about one thirtieth of the weight of the female, and little more than one fourth as long. He exists, in fact, as a parasite on the female, being attached to some soft place, where he draws up the skin into a sort of nipple. The skin of the snout is continuous with that of the female, and no one can tell where one fish leaves off and the other begins. The dorsal angling pole is lost in the male because in his sheltered condition he has no use for bait. The mouth, when retained at all, is used only for breathing. In the particular species represented in the cut, the little male fish hangs on belly upward.

This sort of sex-parasitism is not known in any group of fishes except these devils of the deep sea. Among the higher vertebrates, the only condition analogous is that of a continental duke or count, little, withered and shop-worn, attached to a Chicago heiress.





CHARLES FREDERICK CHANDLER

THE PROGRESS OF SCIENCE

CHARLES FREDERICK CHANDLER

By Ellwood Kendrick

Chandler Memorial Museum, Columbia University

Professor Chandler, who died on August twenty-fifth last in his eighty-ninth year, was an outstanding figure in chemistry in America. He spent his boyhood with his parents in New Bedford, where his father was a merchant. He attended school in his home town, and matriculated at Lawrence Scientific School of Harvard College. While there he met Professor Charles A. Joy, who held the chair of chemistry at Union College, and on his advice, in 1855, proceeded to Göttingen to study with Friederich Woehler, who took him on as his private assistant. From Göttingen he journeyed to Berlin to develop himself in analysis with Heinrich Rose, then returned to make his doctorate in philosophy under Woehler and straightway thereafter came back home at the age of twenty.

He was well equipped for the scientific life. As a boy of fourteen he showed the lively curiosity about chemistry which he retained throughout his days, and he carried on experiments in his own little laboratory in the attic of his father's house. He was greatly impressed by the public lectures of Louis Agassiz which he attended whenever the opportunity offered. He had an amazing capacity for work and he was naturally and congenitally honest.

Chandler was remarkably practical, a quality that probably gave him his slant towards industrial chemistry rather than in the direction of research in pure science. His constant effort was to bring chemistry into use, and he gave slight thought to his own advantage or profit in the matter.

On returning to New Bedford from Germany he found a situation that has grown to be familiar to many men of science; a vast amount of work to be done, but nobody aware of the fact except himself. The gatherers and merchants of whale oil could not see that chemistry had to do with their business. So, learning that his old friend Professor Joy at Union College needed an assistant, he posted off to Schenectady only to discover that the sole position for which funds had been provided by the trustees—and this despite Professor Joy's urgent need—was that of janitor at $500 a year! Chandler took the job, and proceeded to teach chemistry and mineralogy and geology as accessory to sweeping up and cleaning. Within a few months, however, in April, 1857, he succeeded Professor Joy to the chair of chemistry at Union when the latter was called to Columbia College. Young Chandler was twenty-one years of age at the time. In 1864 he came to the Columbia School of Mines and was actively associated with that college and university as a great teacher for fifty-six years, and fifteen more as professor emeritus, making in all the well-nigh unprecedented record of sixty-one years of service. His emolument at first was meager, none the less he gave his work without pay to the study of sanitary problems for the New York Board of Health, to teaching chemistry in the College of Physicians and Surgeons and to the students of the College of Pharmacy. In time he became president of the Board of Health, president of the College of Pharmacy and professor of chemistry

THE FLAMMARION OBSERVATORY AT JUVISY

Here the well-known French astronomer did most of his work and died recently. The observatory occupies an old house which was a favorite stopping place for the kings of France on their way to and from Fontainebleau. It was in this house that Napoleon signed his abdication on the flight from Fontainebleau and the historic table used is one of the prized possessions of the observatory. A movement is on foot among American admirers of the noted scientist to buy and endow the observatory as a permanent Flammarion memorial. This movement is headed by William McAfee, an amateur astronomer of New York and Paris, who is in France at the moment for the purpose of examining the feasibility of his plan.

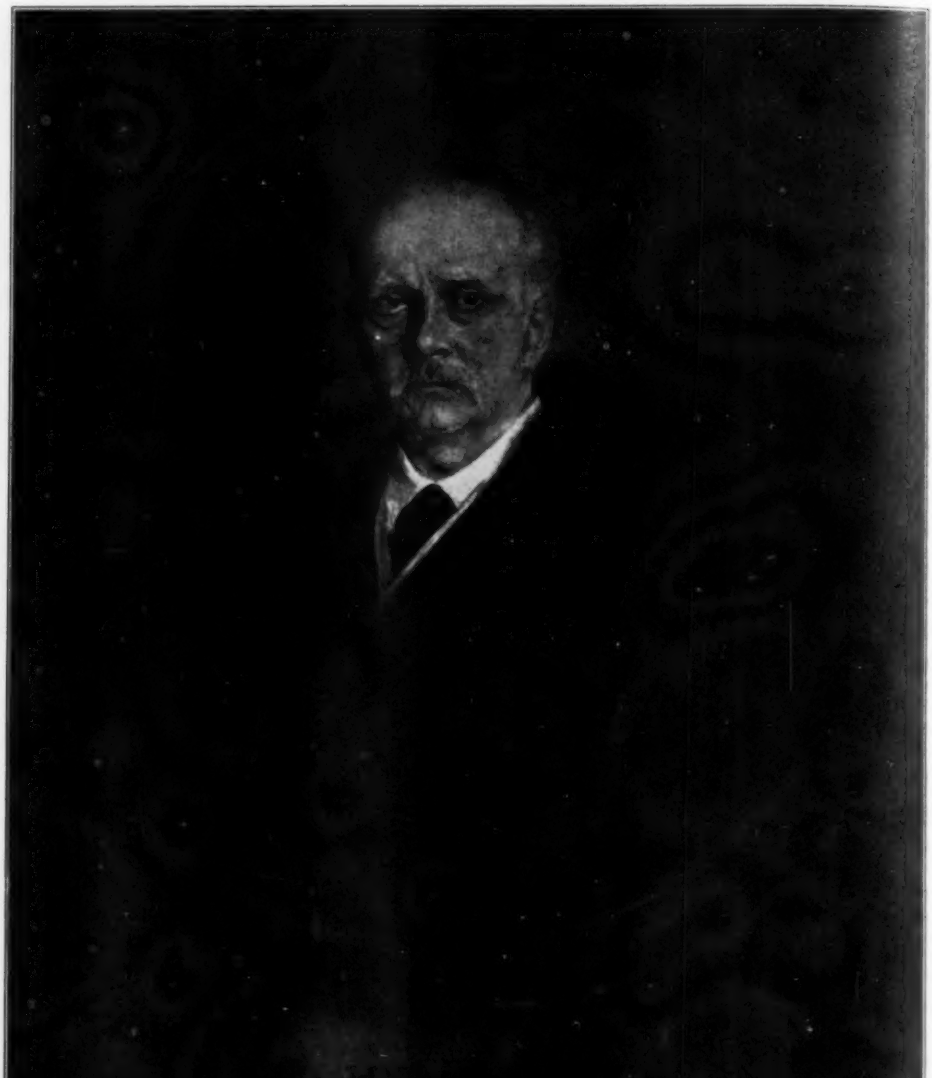
MME. GABRIELLE CAMILLE FLAMMARION

WIDOW OF THE NOTED FRENCH ASTRONOMER. SHE WAS HIS SECRETARY AND COLLABORATOR FROM THE TIME SHE WAS EIGHTEEN YEARS OLD, MARRYING THE NOTED FRENCH SCIENTIST SHORTLY BEFORE HIS DEATH. SHE IS NOW ENGAGED IN PREPARING FOR PUBLICATION SEVERAL OF HIS POSTHUMOUS WORKS.

and of medical jurisprudence at the medical school.

He was a pioneer in sanitation and in raising the standards of pharmacy and of medicine. For a number of years he worked from six to eight o'clock in the mornings in the laboratory of a sugar refining company to eke out his income in order to be able to give more time to the public service. He taught chemistry and taught it well, to some 35,000 students. His lectures were eagerly attended. He did not take out many patents, but gave inventions such as the anti-siphoning device and flush-closet in plumbing to the public. Evidences of his scientific acumen and ingenuity may be found in nearly every industry that engaged him. This explains why the list of his contributions to pure science is not large. He was always intent on putting science to use.

He was president of the State Charities Aid Association for several years, chemical adviser to the U. S. Navy De-



HERMANN VON HELMHOLTZ

FROM THE PORTRAIT PAINTED BY FRANZ VON LENBACH IN 1894.

partment, president of the Street Cleaning Improvement Society which organized the better care of streets, chemist to the Croton Aqueduct Commission, a founder of the American Chemical Society—indeed the list of his many activities would fill pages. He was decorated with honorary doctorates by various American universities and by Oxford. He was a great teacher, a splendid citizen and the pioneer of chemical technology in America.

HERMANN VON HELMHOLTZ AND HIS WORK IN PHYSIOLOGICAL OPTICS

By Dr. Charles Sheard

Mayo Clinic and Mayo Foundation for Medical Education and Research

Monuments are constantly being built to the memory of men and women who have served for the common good and the betterment of mankind. Some of those who are thus honored and revered have been great in war and the stalwart champions of the oppressed, and others, for one reason or another, have been "first in the hearts of their countrymen"; some have been captains of industry, while others have thought not of the loom and the ploughshare, but have labored that man might have the treasure which neither moth nor rust doth corrupt, nor thieves break through and steal. Such men and women have been acclaimed in large measure, first of all, by their own peoples, to be later venerated as citizens of the world. So the scientific world, endeavoring to "prove all things and to hold fast that which is good," has long since acclaimed von Helmholtz as one of the first citizens of the world of fact and truth, and has built to his memory a monument out of the materials which he provided.

The nineteenth century will always be famous for the enunciation of two great generalizations on which all science rests. The twentieth century, with all its marvelous advancement, has not overshadowed these discoveries and their importance nor can it, perchance, point to such a galaxy of names as those of Darwin, Wallace, Maxwell, Pasteur, Kelvin, Joule, Helmholtz and others. And it is to these last three—Helmholtz, Joule and Thomson (Lord Kelvin)—that the world is indebted "for the most important and far-reaching generalization in physical science since the time of Newton," for at the age of twenty-six years Helmholtz produced his paper on the "Conservation of Energy" which constitutes, perchance, the most important piece of work in his career of half a century as an investigator.

At the age of thirty, in the year 1851, Helmholtz invented the ophthalmoscope. When the famous ophthalmologist von Graefe was shown the instrument and saw for the first time the fundus of the living human eye, with its optic disc and its blood vessels, he is said to have exclaimed: "Helmholtz has unfolded to us a new world." It is claimed by some that the credit for the first ophthalmoscope should go to Babbage, an English mathematician, who, in 1847, exhibited to Wharton Jones, the distinguished London oculist, the model of an instrument invented by him for examining the interior of the eye. This device, however, was not made known to the world by Jones until 1854. At any rate, the independence of the workers and the self-sufficiency of the labors of each of these men—resulting in the invention of one of the most marvelous and useful instruments for observation and diagnosis in the field of medicine—may warrant the linking toegther of the names of Helmholtz and Babbage. For there is glory enough for both.

In 1855 Helmholtz became professor of anatomy and physiology at Bonn and

four years later accepted a like professorship at the University of Heidelberg, where he remained for a dozen years. During these years (1855–66) he wrote his great treatise on *Physiological Optics*, which appeared in three parts. This treatise is, without question, the most important book on the physiology, psychology and physics of vision which has ever been penned. In 1862 he published his work on *Sensations of Tone*, which may well be termed the principia of physiological acoustics.

Helmholtz's earliest work in physiological optics dealt with the refractive apparatus of the eye and to this he brought the exactness of training and the viewpoint of a physicist and the desire to understand and interpret the functions of the eye and the ultimate nature of the visual mechanism in terms of general optical theory. By means of the ophthalmometer and the phakoscope, which he invented, Helmholtz obtained many data on the eye as an optical instrument, as well as on the accommodative mechanism. Possibly the theory of accommodation as laid down by Helmholtz may not stand the test of time, but it is to be questioned whether any equally satisfactory alternative explanation has as yet appeared. His skill as an anatomist and his knowledge of general optical science made all these things possible and enabled him to pioneer in the catoptrics and dioptrics of the human eye.

Helmholtz's interest in the ultimate mechanism of the visual function led him to advocate a definite hypothesis as to the physiological processes or operations underlying color vision. Perhaps the theory should be called the Young-Helmholtz-Maxwell theory. Helmholtz gave the hypothesis of Young a definite "standing in court" in terms of established principles. Of course, he did not prove his color hypothesis and raise it from the realm of a guess to that of a fact; neither, in the best judgment of those competent, has anybody else proved another conception in the matter of color vision. Besides his color hypothesis, Helmholtz developed the color triangle to a point beyond that to which it had previously been carried and made clear the difference between additive and subtractive mixtures of colors.

Problems of binocular vision and the theory of space perception occupied Helmholtz's attention. He demonstrated that, in his own eyes, the retinal horizontals are parallel to the true horizon, while the apparent verticals are inclined to one another at an angle of about two to three degrees. The interpretation of these observations and phenomena, as well as the universality of their existence, are still much discussed and are open to further proof. On the basis of his data Helmholtz recalculated the form of the horopter, which is the locus of points that fall on corresponding retinal points in binocular vision. His power as a mathematical physicist enabled him to analyze with great accuracy ocular movements and to show that the complicated adjustments of the two eyes are all governed and controlled by the fundamental principle that all objects shall be seen singly so far as such is possible.

At Rochester, New York, October 25, 1921, the Optical Society of America held a Helmholtz memorial meeting, being the observance of the hundredth anniversary of his brithday, at which addresses were made by Professors Southall, of Columbia, Crew, of Northwestern, Pupin, of Columbia, and Dr. Troland, of Harvard. Following this meeting, ways and means were provided for preparing and publishing an English translation of the *Physiologischen Optik* so that there might become available to the English reading world "that great Bible of physiological optics which Helmholtz so painstakingly prepared for us." Dr. James P. C. Southall, a pro-

fessor of physics at Columbia University, was selected as editor-in-chief. The first volume of the translation appeared in 1924, the second during the past year and the third volume, completing this worth-while labor of love, came out in January of this year.

Of the *Treatise on Physiological Optics*, we know of no statement which more clearly expresses the truth than that by Professor Southall, as he writes in the preface to the English translation: "Apart from its own intrinsic value, the treatise on *Physiological Optics* is a model of scientific method and logical procedure that has hardly ever been excelled in these respects."

Of von Helmholtz himself, no finer or truer tribute was ever penned than by London *Punch* in a brief stanza which appeared shortly after the announcement of his death:

What matters titles, Helmholtz is a name
That challenges alone the award of fame.
When emperors, kings, pretenders, shadows all,
Leave not a dust trace on our whirling ball
Thy work, O grave-eyed searcher, shall endure
Unmarred by faction, from low passion pure.

ADDRESS TO THE RHAMPHORHYNCHUS

By W. A. Spalding
Los Angeles, Cal.

Preposterous Pterodactyl, looming large
In scientific thought and speculation,
What was thy province on the early marge
Of animal creation?

With form outlandish and out-sea-ish too,
(The merest contemplation makes one shudder),—
A tail extending almost out of view,
And ending in a rudder;

A monster lizard, Brobdignagian bird,
Reptile and fish, with every ghastly feature,
A crocodile with wings,—a most absurd,
A most unsightly creature.

If physiognomy be any guide,
(It seldom leads us into grievous errors),
You were the oger of the whole world wide,
The holiest of terrors.

And when you issued from the troubled sea
Upon the stricken land, or over,
All monsters of a less acute degree
Began to hunt for cover.

Smilodon smiled, and left instanter;
Hadrosaurus went with a lope and a canter;
Cinnolisaur's coils began to unlimber;
Megalosaurus struck for the tall, tall timber;
Teratornis flew, with squawk and a flutter,
Iguanadon's hops were too utterly utter;
Laelaps leaped wildly o'er bushes and stubble;
Elasmosaur wiggled away from the trouble;
Dinosaurus dove for the muddy bottom;—
And if any remained, Rhamphorhynchus, you *got* 'm.

But the primitive world was a world of change;
The orders were then what the present command is;
Exuberant life means a limited range;—
You succumbed to *Mutatis Mutandis.*

And so, Pterodactyl fierce and great,
This history must be related:
Your license was revoked by Fate,
Your rights were sequestrated.

It was long ago,—so long indeed
We scarce can comprehend the distance;—
Some buried strata bear the screed
Of your condign existence.

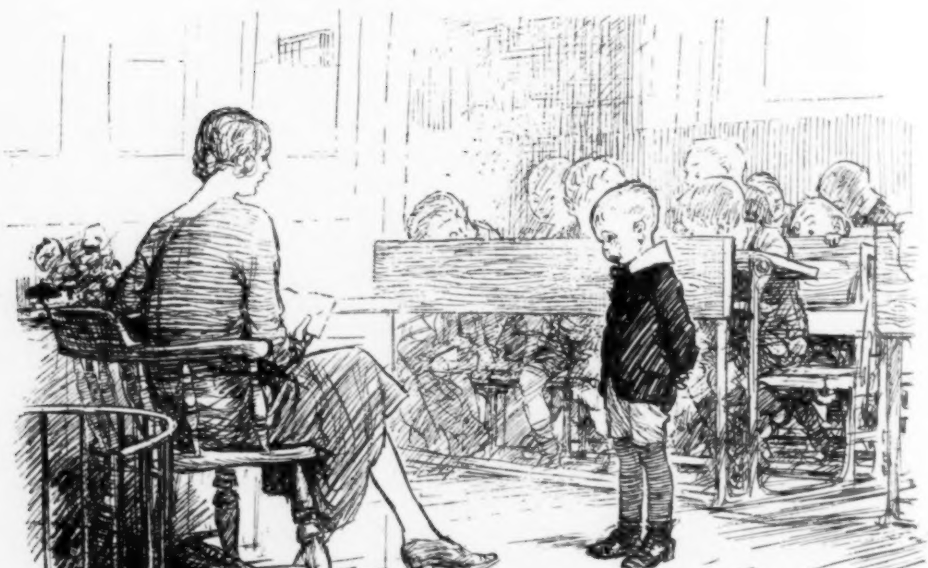
Suggestions of your form and size,—
Some aspect of your manners,
Are still displayed before our eyes
On gorgeous Chinese banners;

And frazzled fragments of your frame,
Trussed up in some museum,
Bear testimony of your name
To those who go and see 'em.

If, in this tale I could descry
Some slightly moral notion,
'Twould be, old boy, you aimed too high
For earth and air and ocean.

And so, to cap your many frills,
To climax your ambition,
You went to smash with motor ills,
And burned out your ignition.

WHERE IS THE TOOTHACHE?



Teacher. "WHY WEREN'T YOU AT SCHOOL YESTERDAY, TOMMY?"
Tommy. "PLEASE, TEACHER, I HAD THE TOOTHACHE."
Teacher. "I SEE. AND IS THE TOOTH ACHING STILL?"
Tommy. "I DUNNO, TEACHER. DENTIST 'S GOT IT."

—*From Punch.*